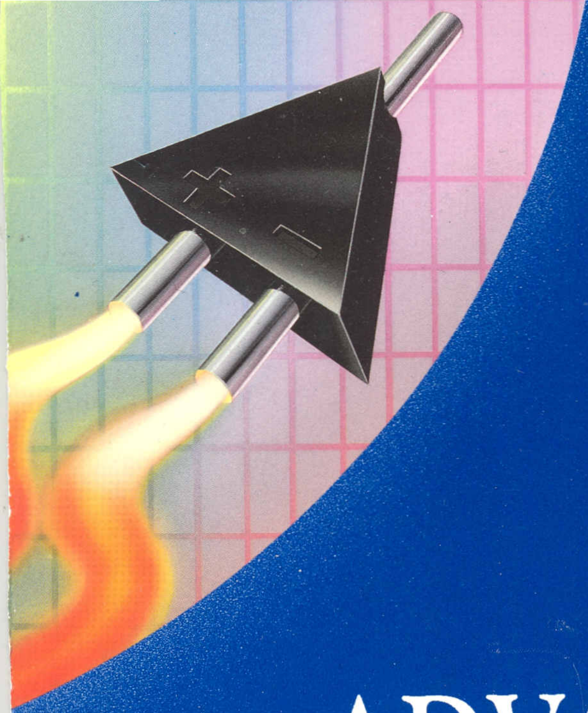

# ADVANCED LINEAR

## NEW PRODUCT SPECIFICATIONS

TEXAS INSTRUMENTS

## Linear Products Quick Reference Guide

| Data Book | Contents | Document No. |
|---|---|---|
| ● Linear Circuits Vol 1 Amplifiers, Comparators, and Special Functions | Operational Amplifiers<br>Voltage Comparators<br>Video Amplifiers<br>Hall-Effect Devices<br>Timers and Current Mirrors<br>Magnetic-Memory Interface<br>Frequency-to-Voltage Converters<br>Sonar Ranging Circuits/Modules<br>Sound Generators | SLYD003, 1989 |
| ● Linear Circuits Vol 2 Data Acquisition and Conversion | A/D and D/A Converters<br>DSP Analog Interface<br>Analog Switches and Multiplexers<br>Switched-Capacitor Filters | SLYD004, 1989 |
| ● Linear Circuits Vol 3 Voltage Regulators and Supervisors | Supervisor Functions<br>Series-Pass Voltage Regulators<br>Shunt Regulators<br>Voltage References<br>DC-to-DC Converters<br>PWM Controllers | SLYD005, 1989 |
| ● Linear Circuits | Operational Amplifier Macromodels | SLOS047, 1990 |
| ● Linear Circuits | SN75C091 SCSI Bus Controller | SLLS064, 1990 |
| ● Optoelectronics and Image Sensors | Optocouplers<br>CCD Image Sensors and Support<br>Phototransistors<br>IR-Emitting Diodes<br>Hybrid Displays | SOYD002A,1990 |
| ● Speech System Manuals | TSP50C4X Family | SPSS010, 1990 |
|  | TSP50C10/11 Synthesizer | SPSS011, 1990 |
|  | TSP53C30 Synthesizer | SPSV003, 1990 |
| ● Interface Circuits | Data Transmission and Control Circuits, Peripheral Drivers/Power Actuators, Display Drivers | SLYD006, 1991 |

As of January 1991

# Advanced Linear
# New Product Specifications

TEXAS
INSTRUMENTS

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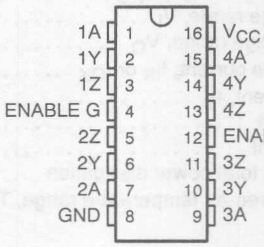
# AM26C31C, AM26C31I
# QUADRUPLE DIFFERENTIAL LINE DRIVERS

D3636, DECEMBER 1990–REVISED MARCH 1991

- Meets EIA Standard RS-422-A and CCITT Recommendation V.11
- Low Power, $I_{CC}$ = 100 μA Typ
- Operates From a Single 5-V Supply
- High Speed, $t_{PLH} = t_{PHL}$ = 7 ns Typ
- Low Pulse Distortion ($t_{sk(p)}$ = 0.5 ns Typ)
- High Output Impedance in Power-Off Conditions
- Improved Replacement for AM26LS31

D OR N PACKAGE
(TOP VIEW)



FUNCTION TABLE (EACH DRIVER)

| INPUT | ENABLES | | OUTPUTS | |
|---|---|---|---|---|
| A | G | $\overline{G}$ | Y | Z |
| H | H | X | H | L |
| L | H | X | L | H |
| H | X | L | H | L |
| L | X | L | L | H |
| X | L | H | Z | Z |

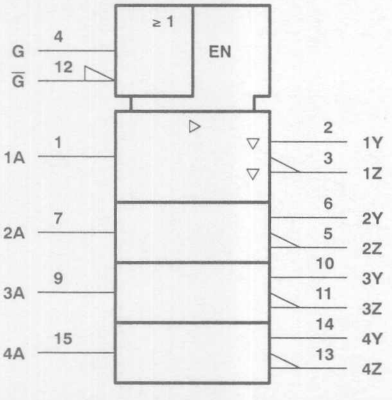
H = high level
L = low level
X = irrelevant
Z = high impedance (off)

## description

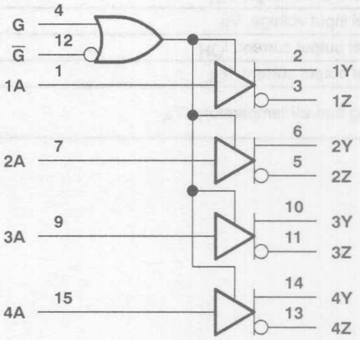
The AM26C31C and AM26C31I are quadruple complementary-output line drivers designed to meet the requirements of EIA Standard RS-422-A and CCITT V.11. The 3-state outputs have high-current capability for driving balanced lines such as twisted-pair or parallel-wire transmission lines, and they provide a high-impedance state in the power-off condition. The enable function is common to all four drivers and offers the choice of an active-high or active-low enable input. BiCMOS circuitry reduces power consumption without sacrificing speed.

The AM26C31C is characterized for operation from 0°C to 70°C and the AM26C31I is characterized for operation from − 40°C to 85°C.

## logic symbol†



## logic diagram (positive logic)



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† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC Publication 617-12.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|---|
| Supply voltage range, $V_{CC}$ (see Note 1) | – 0.5 V to 7 V |
| Input voltage range, $V_I$ | – 0.5 V to $V_{CC}$ + 0.5 V |
| Output voltage range, $V_O$ | – 0.5 V to 7 V |
| Clamp diode current, $I_{IK}$ or $I_{OK}$ | ± 20 mA |
| Output current, $I_O$ | ± 150 mA |
| $V_{CC}$ current | 200 mA |
| GND current | – 200 mA |
| Continuous total power dissipation | See Dissipation Rating Table |
| Operating free-air temperature range, $T_A$: AM26C31C | 0°C to 70°C |
| AM26C31I | – 40°C to 85°C |
| Storage temperature range | – 65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: All voltage values, except differential output voltage $V_{OD}$, are with respect to network ground terminal.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \le 25°C$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25°C$ | $T_A = 70°C$ POWER RATING | $T_A = 85°C$ POWER RATING |
|---|---|---|---|---|
| D | 950 mW | 7.6 mW/°C | 608 mW | 494 mW |
| N | 1150 mW | 9.2 mW/°C | 736 mW | 598 mW |

## recommended operating conditions

| | | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|---|
| Supply voltage, $V_{CC}$ | | 4.5 | 5 | 5.5 | V |
| High-level input voltage, $V_{IH}$ | | 2 | | | V |
| Low-level input voltage, $V_{IL}$ | | | | 0.8 | V |
| High-level output current, $I_{OH}$ | | | | – 20 | mA |
| Low-level output current, $I_{OL}$ | | | | 20 | mA |
| Operating free-air temperature, $T_A$ | AM26C31C | 0 | | 70 | °C |
| | AM26C31I | – 40 | | 85 | |

## electrical characteristics over recommended operating free-air temperature range (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | MIN | TYP† | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $V_{OH}$ | High-level output voltage | $I_O = -20$ mA | | 2.4 | 3.4 | | V |
| $V_{OL}$ | Low-level output voltage | $I_O = 20$ mA | | | 0.2 | 0.4 | V |
| $\lvert V_{OD} \rvert$ | Differential output voltage | $R_L = 100\ \Omega$ | | 2 | 3.1 | | V |
| $\Delta \lvert V_{OD} \rvert$ | Change in magnitude of differential output voltage‡ | $R_L = 100\ \Omega$ | | | | ± 0.4 | V |
| $V_{OC}$ | Common-mode output voltage | $R_L = 100\ \Omega$ | | | | 3 | V |
| $\Delta \lvert V_{OC} \rvert$ | Change in magnitude of common-mode output voltage‡ | $R_L = 100\ \Omega$ | | | | ± 0.4 | V |
| $I_I$ | Input current | $V_I$ at $V_{CC}$, $V_{IH}$, $V_{IL}$, or GND | | | | ± 1 | μA |
| $I_{O(off)}$ | Driver output current with power off | $V_{CC} = 0$, | $V_O = 6$ V | | | 100 | μA |
| | | $V_{CC} = 0$, | $V_O = -0.25$ V | | | – 100 | |
| $I_{OS}$ | Driver output short-circuit current | $V_O = 0$ | | – 30 | | – 150 | mA |
| $I_{OZ}$ | Off-state (high-impedance state) output current | $V_O = 2.5$ V | | | | 20 | μA |
| | | $V_O = 0.5$ V | | | | – 20 | μA |
| $I_{CC}$ | Quiescent supply current | $I_O = 0$, | $V_I = 0$ or 5 V | | | 100 | μA |
| | | $I_O = 0$,<br>See Note 2 | $V_I = 2.4$ or 0.5 V, | | 1.5 | 3.0 | mA |
| $C_i$ | Input capacitance | | | | 6 | | pF |

† All typical values are at $V_{CC} = 5$ V and $T_A = 25°C$.

‡ $\Delta \lvert V_{OD} \rvert$ and $\Delta \lvert V_{OC} \rvert$ are the changes in magnitude of $V_{OD}$ and $V_{OC}$, respectively, that occur when the input is changed from a high level to a low level.

NOTE 2: Measured per input. All other inputs are at 0 or 5 V.

## switching characteristics, $V_{CC} = 5$ V, $T_A = 25°C$

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| $t_{PLH}$ | Propagation delay time, low-to-high-level output | See Figures 1 and 2, S1 is open | | 7 | 12 | ns |
| $t_{PHL}$ | Propagation delay time, high-to-low-level output | | | 7 | 12 | ns |
| $t_{sk(p)}$ | Pulse skew ($\lvert t_{PLH} - t_{PHL} \rvert$) | | | 0.5 | 4 | ns |
| $t_{rD}$, $t_{fD}$ | Differential output rise and fall times | See Figures 1 and 4, S1 is open | | 5 | 10 | ns |
| $t_{PZH}$ | Output enable time to high level | See Figures 1 and 3, S1 is closed | | 10 | 19 | ns |
| $t_{PZL}$ | Output enable time to low level | | | 10 | 19 | ns |
| $t_{PHZ}$ | Output disable time from high level | | | 7 | 16 | ns |
| $t_{PLZ}$ | Output disable time from low level | | | 7 | 16 | ns |
| $C_{pd}$ | Power dissipation capacitance (see Note 3) | No load, $T_A = 25°C$ | | 100 | | pF |

NOTE 3: $C_{pd}$ is used to estimate the switching losses according to $P_D = C_{pd} V_{CC}^2 f$ where $P_D$ is in watts, $C_{pd}$ is in farads, $V_{CC}$ is in volts, and f is in hertz.

## PARAMETER MEASUREMENT INFORMATION

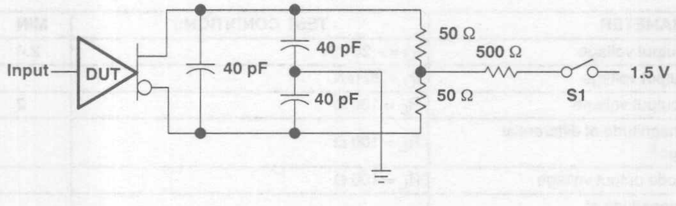


Figure 1. Test Circuit

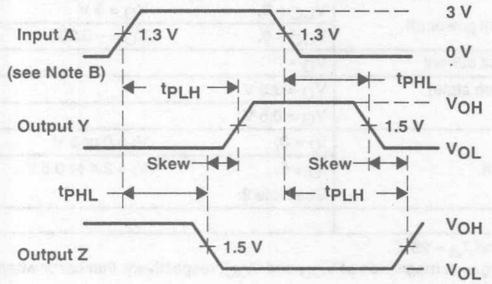


Figure 2. Propagation Delay Times and Skew Waveforms

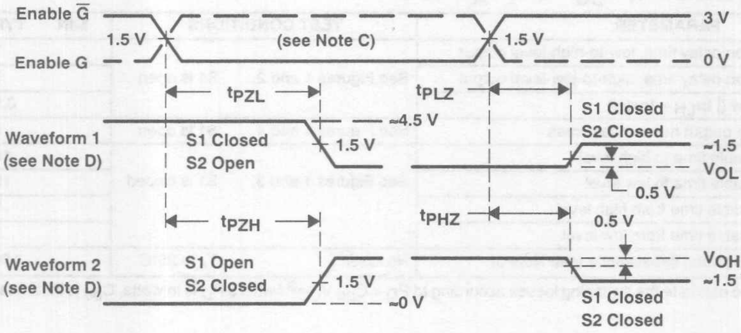


Figure 3. Enable and Disable Time Waveforms

NOTES:
A. All input pulses are supplied by generators having the following characteristics: PRR ≤ 1 MHz, $Z_O \approx 50\ \Omega$, $t_r \leq 15$ ns, and $t_f \leq 6$ ns.
B. When measuring propagation delay times and skew, switch S1 is open.
C. Each enable is tested separately.
D. Waveform 1 is for an output with internal conditions such that the output is low except when disabled by the output control. Waveform 2 is for an output with internal conditions such that the output is high except when disabled by the output control.

## PARAMETER MEASUREMENT INFORMATION

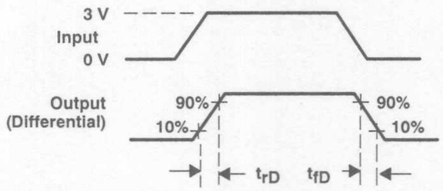


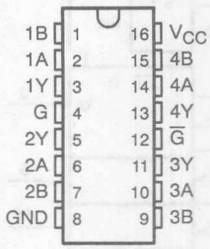
Figure 4. Differential Rise and Fall Times

# AM26C32C, AM26C32I
# QUADRUPLE DIFFERENTIAL LINE RECEIVERS

D3634, DECEMBER 1990 – REVISED FEBRUARY 1991

- **Meets EIA Standards RS-422-A, RS-423-A, and CCITT Recommendation V.11**
- **Low Power, $I_{CC}$ = 9 mA Typ**
- **±7-V Common-Mode Range With ± 200-mV Sensitivity**
- **Input Hysteresis . . . 60 mV Typical**
- **$t_{pd}$ = 19 ns (Typ)**
- **Operates From a Single 5-V Supply**
- **3-State Outputs**
- **Input Fail-Safe Circuitry**
- **Improved Replacement for AM26LS32**

**D OR N PACKAGE**
**(TOP VIEW)**



## description

The AM26C32C and AM26C32I are quadruple line receivers for balanced and unbalanced digital data transmission. The enable function is common to all four receivers and offers a choice of active-high or active-low input. Three-state outputs permit connection directly to a bus-organized system. Fail-safe design ensures that if the inputs are open, the outputs will always be high.

The AM26C32 is manufactured using a BiCMOS process, which is a combination of bipolar and CMOS transistors. This process provides the high-voltage and current of bipolar with the low power of CMOS to reduce the power consumption to about one-fifth that of the standard AM26LS32 while still maintaining ac and dc performance.

The AM26C32C is characterized for operation from 0°C to 70°C and the AM26C32I is characterized from – 40°C to 85°C.

**FUNCTION TABLE**
**(each receiver)**

| DIFFERENTIAL INPUT | ENABLES | | OUTPUT |
|---|---|---|---|
| | G | $\overline{G}$ | |
| $V_{ID} \geq V_{TH}$ | H | X | H |
| | X | L | H |
| $V_{TL} \leq V_{ID} \leq V_{TH}$ | H | X | ? |
| | X | L | ? |
| $V_{ID} \leq V_{TH}$ | H | X | L |
| | X | L | L |
| X | L | H | Z |

H = high level, L = low level, X = irrelevant
Z = high impedance (off), ? = indeterminate

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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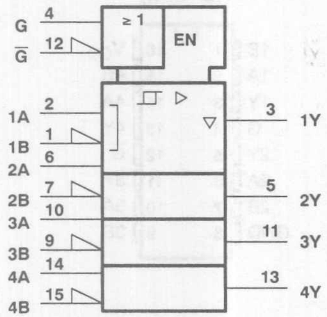
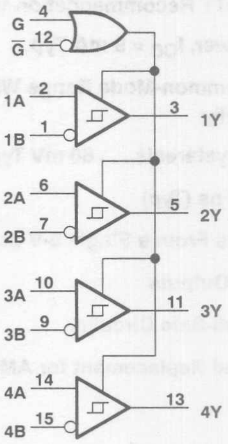
### logic symbol†



† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC Publication 617-12.

### logic diagram (positive logic)



### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|---|
| Supply voltage, $V_{CC}$ (see Note 1) | 7 V |
| Input voltage range, $V_I$: A or B inputs | −12 to 14 V |
| G or $\overline{G}$ inputs | 7 V |
| Output voltage, $V_O$ | 7 V |
| Output current, $I_O$ | ±25 mA |
| Continuous total power dissipation | See Dissipation Rating Table |
| Operating free-air temperature range, $T_A$: AM26C32C | 0°C to 70°C |
| AM26C32I | −40°C to 85°C |
| Storage temperature range | −65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: All voltage values, except differential output voltage $V_{OD}$, are with respect to network ground terminal. Currents into the device are positive and currents out of the device are negative.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \le 25°C$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25°C$ | $T_A = 70°C$ POWER RATING | $T_A = 85°C$ POWER RATING |
|---|---|---|---|---|
| D | 950 mW | 7.6 mW/°C | 608 mW | 494 mW |
| N | 1150 mW | 9.2 mW/°C | 736 mW | 598 mW |

## recommended operating conditions

| | | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|---|
| Supply voltage, $V_{CC}$ | | 4.5 | 5 | 5.5 | V |
| High-level input voltage, $V_{IH}$ | | 2 | | | V |
| Low-level input voltage, $V_{IL}$ | | | | 0.8 | V |
| Common-mode input voltage, $V_{IC}$ | | | | ± 7 | V |
| High-level output current, $I_{OH}$ | | | | – 6 | mA |
| Low-level output current, $I_{OL}$ | | | | 6 | mA |
| Operating free-air temperature, $T_A$ | AM26C32C | 0 | | 70 | °C |
| | AM26C32I | – 40 | | 85 | |

## electrical characteristics over recommended ranges of $V_{CC}$, $V_{IC}$, and operating free-air temperature (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | MIN | TYP† | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $V_{TH}$ | Differential input high-threshold voltage | $V_O = V_{OH}$ min, | $I_{OH} = -440\ \mu A$ | | | 0.2 | V |
| $V_{TL}$ | Differential input low-threshold voltage | $V_O = 0.45$ V, | $I_{OL} = 8$ mA | – 0.2‡ | | | V |
| $V_{hys}$ | Hysteresis, $V_{T+} - V_{T-}$ | | | | 60 | | mV |
| $V_{IK}$ | Enable input clamp voltage | $V_{CC}$ = MIN, | $I_I = -18$ mA | | | – 1.5 | V |
| $V_{OH}$ | High-level output voltage | $V_{ID} = 200$ mV, | $I_{OH} = -6$ mA | 2.7 | | | V |
| $V_{OL}$ | Low-level output voltage | $V_{ID} = -200$ mV, | $I_{OL} = 6$ mA | | 0.2 | 0.3 | V |
| $I_{OZ}$ | Off-state (high-impedance-state) output current | $V_O = V_{CC}$ or GND | | | ± 0.5 | ± 5 | µA |
| $I_I$ | Line input current | $V_I = 10$ V, | Other input at 0 V | | | 1.5 | mA |
| | | $V_I = -10$ V, | Other input at 0 V | | | – 2.5 | |
| $I_{IH}$ | High-level enable current | $V_I = 2.7$ V | | | | 20 | µA |
| $I_{IL}$ | Low-level enable current | $V_I = 0.4$ V | | | | – 100 | µA |
| $r_i$ | Input resistance | One input to ac ground | | | 17 | | kΩ |
| $I_{CC}$ | Supply current | $V_{CC}$ = MAX | All outputs disabled | | 9 | 14 | mA |
| | | | All outputs enabled | | 12 | | |

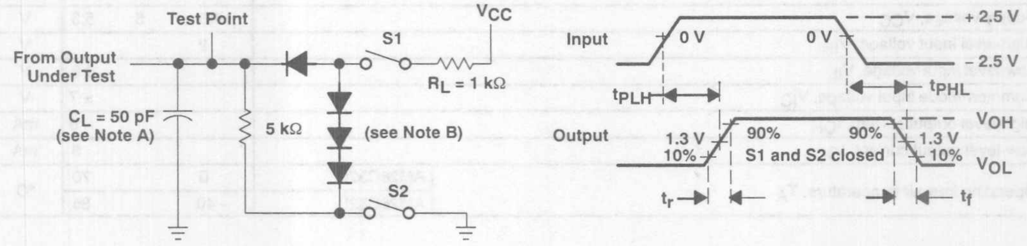
## switching characteristics over recommended ranges of $V_{CC}$, $V_{IC}$, and operating free-air temperature (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|---|---|---|---|---|---|---|
| $t_{PLH}$ | Propagation delay time, low-to-high-level output | See Figure 1 | 10 | 19 | 30 | ns |
| $t_{PHL}$ | Propagation delay time, high-to-low-level output | | 10 | 19 | 30 | ns |
| $t_f$ | Output fall time | See Figure 1 | | 4 | 9 | ns |
| $t_r$ | Output rise time | | | 4 | 9 | ns |
| $t_{PZH}$ | Output enable time to high level | See Figure 1 | | 13 | 22 | ns |
| $t_{PZL}$ | Output enable time to low level | | | 13 | 22 | ns |
| $t_{PHZ}$ | Output disable time from high level | See Figure 1 | | 13 | 22 | ns |
| $t_{PLZ}$ | Output disable time from low level | | | 13 | 22 | ns |

† All typical values are at $V_{CC} = 5$ V, $T_A = 25°C$, and $V_{IC} = 0$.

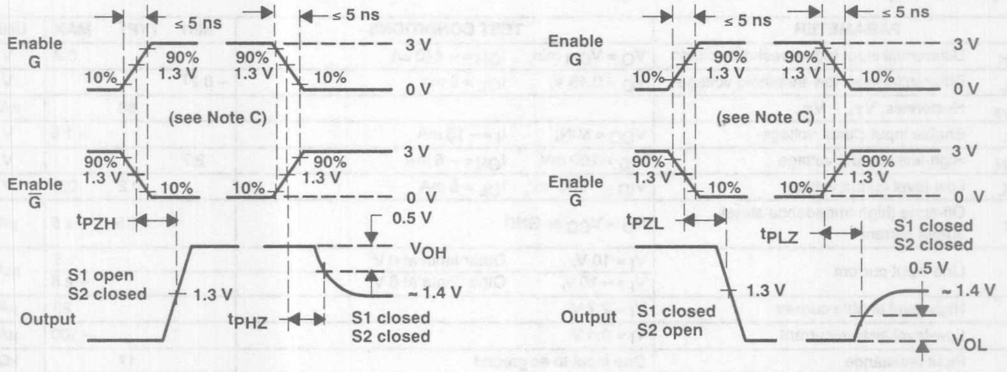
‡ The algebraic convention, where the less positive (more negative) limit is designated as minimum, is used in this data sheet for threshold levels only.

## PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

VOLTAGE WAVEFORMS FOR $t_{PLH}$, $t_{PHL}$



VOLTAGE WAVEFORMS FOR $t_{PHZ}$, $t_{PZH}$

VOLTAGE WAVEFORMS FOR $t_{PLZ}$, $t_{PZL}$

NOTES: A. $C_L$ includes probe and jig capacitance.
B. All diodes are 1N3064 or equivalent.
C. Enable G is tested with $\overline{G}$ high; $\overline{G}$ is tested with G low.

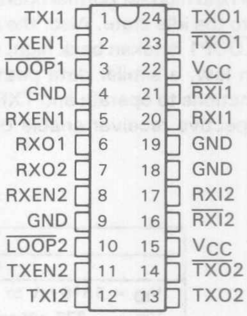
Figure 1

# SN75ALS085
# LAN ACCESS UNIT INTERFACE DUAL DRIVER/RECEIVER

D3279, APRIL 1989

- **Compatible with IOS 8802.3:1989 and ANSI/IEEE Std 802.3-1988**
- **Interdevice Loop-Back Paths for System Testing**
- **Squelch Function Implemented on the Receiver Inputs**
- **Drivers Will Drive a Balanced 78-Ω Load**
- **Transformer Coupling Not Required in System**
- **Power-Up/Power-Down Protection (Glitch-Free)**
- **Isolated Ground Pins for Reduced Noise Coupling**
- **Fault-Condition Protection Built into the Device**
- **Driver Inputs Are Level-Shifted ECL Compatible**

**NT**
**DUAL-IN-LINE PACKAGE**
**(TOP VIEW)**


TXI1 1
TXEN1 2
$\overline{\text{LOOP1}}$ 3
GND 4
RXEN1 5
RXO1 6
RXO2 7
RXEN2 8
GND 9
$\overline{\text{LOOP2}}$ 10
TXEN2 11
TXI2 12
24 TXO1
23 $\overline{\text{TXO1}}$
22 $V_{CC}$
21 $\overline{\text{RXI1}}$
20 RXI1
19 GND
18 GND
17 RXI2
16 $\overline{\text{RXI2}}$
15 $V_{CC}$
14 $\overline{\text{TXO2}}$
13 TXO2

## description

The SN75ALS085 is a monolithic, high-speed, advanced low-power Schottky, dual-channel driver/receiver device designed for use in the AUI of ANSI/IEEE Std 802.3-1988. The two drivers on the device will drive a 78-Ω balanced, terminated twisted-pair transmission line up to a maximum length of 50 meters. In the off (idle) state, the drivers will maintain minimal differential output voltage on the twisted-pair line and, at the same time, remain within the required output common-mode range.

With the driver enable (TXEN) high, upon receiving the first falling edge into the driver input, the differential outputs will rise to full-amplitude output levels within 25 ns. The output amplitude will be maintained for the remainder of the packet. After the last positive packet edge transmitted into the driver, the driver will maintain a minimum of 70% of full differential output for a minimum of 200 ns, then decay down to a minimum level for the reset (idle) condition within 8 μs. Disabling the driver by taking the driver enable low will also force the output into the idle condition after the normal 8-μs timeout. While operating, the driver is able to withstand a set of fault conditions and not suffer damage due to the faults being applied. The drivers will power up in the idle state to ensure that no activity is placed on the twisted-pair cable that could be interpreted as network traffic.

The line receiver squelch function interfaces to a differential twisted-pair line terminated external to the device. The receiver squelch circuit allows differential receive signals to pass through as long as the input amplitude and pulse duration are greater than the minimum squelch threshold. This assures a good signal-to-noise ratio while the data path is active and prevents system noise from causing false data transitions during line shut down and line-idle conditions. The RXO outputs default to a high level and the RXEN outputs default to a low level while the squelch function is blocking the data path through the receiver (idle). The line receiver squelch will become active within 50 ns when the input squelch threshold is exceeded. The RXEN pin will be driven high while the squelch circuit is allowing data to pass through the receiver. The receiver squelch circuit will also withstand a set of fault conditions while operating without causing permanent damage to the device.

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The purpose of the loop functions is to provide a means by which system data path verification can be done to isolate faulty interfaces and assist in network diagnosis. The LOOP pins are TTL compatible and must be held high for normal operation. When $\overline{\text{LOOP1}}$ is taken low, the output of driver 1 (TXO1) immediately goes into the idle state. Also, the input to receiver 1 is ignored and a path from TXI1 to RXO1 is established. When $\overline{\text{LOOP1}}$ is taken back high, driver 1 and receiver 1 revert back to their normal operation. When $\overline{\text{LOOP2}}$ is taken low, a similar data path is established between TXI1 and RXO2. TXEN1 must be high for the loop functions to operate and TXEN1 can be used to gate the loop function if desired. During loop operation, the respective receiver enable output (RXEN) will reflect the status of TXEN1.

**RECEIVER FUNCTION TABLE**

**$\overline{\text{LOOP}}$ = H**

| | | OUTPUTS | |
|---|---|---|---|
| **RXI** | **PREVIOUS RXEN** | **RXEN** | **RXO** |
| $V_{ID}$ = 1315 mV to −175 mV, $t_w < 25$ ns | L | L | H |
| $V_{ID}$ = −275 mV to −1315 mV, $t_w > 50$ ns | X | H | L |
| $V_{ID}$ = 318 mV to 1315 mV, $t_w < 130$ ns | H | H | H |
| $V_{ID}$ = 318 mV to 1315 mV, $t_w > 175$ ns | X | L | H |

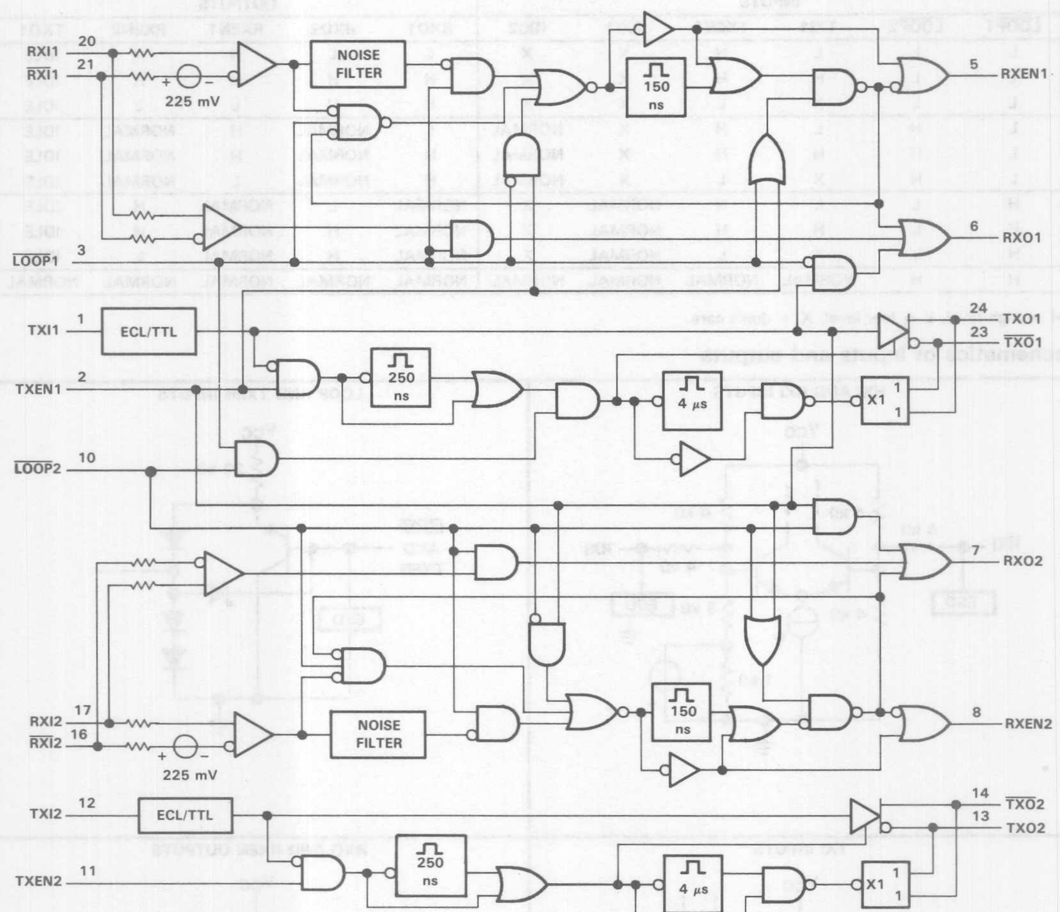
**DRIVER FUNCTION TABLE**

**$\overline{\text{LOOP}}$ = H**

| TXI | TXEN | PREVIOUS TXO | OUTPUT TXO |
|---|---|---|---|
| L | L | IDLE | IDLE |
| H | L | IDLE | IDLE |
| ↓ | H | IDLE | L |
| L | H | ACTIVE | L |
| H < 200 ns | H | ACTIVE | H |
| H > 8 μs | H | ACTIVE | IDLE |
| L | L > 8 μs | ACTIVE | IDLE |
| H < 200 ns | L > 8 μs | ACTIVE | IDLE |
| H < 200 ns | L < 200 ns | ACTIVE | H |
| H > 8 μs | L < 200 ns | ACTIVE | IDLE |
| L | L < 200 ns | ACTIVE | L |

$H = V_I \geq V_T$ max, $L = V_I \leq V_T$ min

## logic diagram (positive logic)



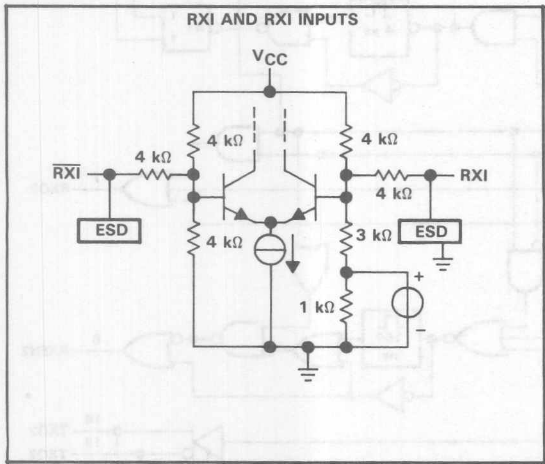
LOOP FUNCTION TABLE

| INPUTS | | | | | | OUTPUTS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| $\overline{\text{LOOP}}$1 | $\overline{\text{LOOP}}$2 | TXI1 | TXEN1 | RXI1 | RXI2 | RXO1 | RXO2 | RXEN1 | RXEN2 | TXO1 |
| L | L | L | H | X | X | L | L | H | H | IDLE |
| L | L | H | H | X | X | H | H | H | H | IDLE |
| L | L | X | L | X | X | H | H | L | L | IDLE |
| L | H | L | H | X | NORMAL | L | NORMAL | H | NORMAL | IDLE |
| L | H | H | H | X | NORMAL | H | NORMAL | H | NORMAL | IDLE |
| L | H | X | L | X | NORMAL | H | NORMAL | L | NORMAL | IDLE |
| H | L | L | H | NORMAL | X | NORMAL | L | NORMAL | H | IDLE |
| H | L | H | H | NORMAL | X | NORMAL | H | NORMAL | H | IDLE |
| H | L | X | L | NORMAL | X | NORMAL | H | NORMAL | L | IDLE |
| H | H | NORMAL | NORMAL | NORMAL | NORMAL | NORMAL | NORMAL | NORMAL | NORMAL | NORMAL |

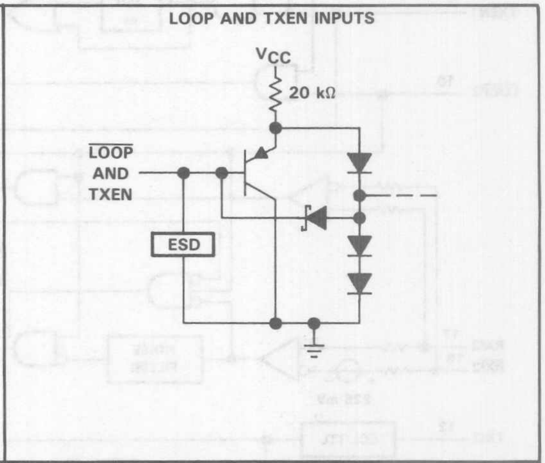
H = high level, L = low level, X = don't care

## schematics of inputs and outputs

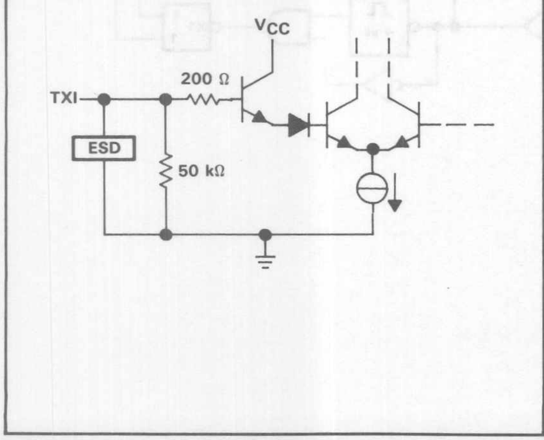
$\overline{\text{RXI}}$ AND RXI INPUTS



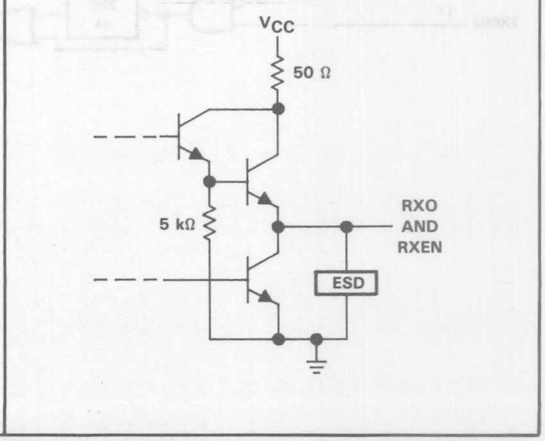
LOOP AND TXEN INPUTS



TXI INPUTS



RXO AND RXEN OUTPUTS



## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|---|
| Supply voltage, $V_{CC}$ (see Note 1) | 6 V |
| TXI and $\overline{\text{LOOP}}$ input voltage | 5.5 V |
| TXO and $\overline{\text{TXO}}$ output voltage | 16 V |
| RXI and $\overline{\text{RXI}}$ input voltage | 16 V |
| RXO and RXEN output voltage | 5.5 V |
| Continuous total power dissipation at (or below) 25 °C (see Note 2) | 1250 mW |
| Operating free-air temperature range | 0 °C to 70 °C |
| Storage temperature range | −65 °C to 150 °C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260 °C |

NOTES: 1. Voltage values are with respect to network ground terminal.
2. For operation above 25 °C free-air temperature, derate linearly to 800 mW at 70 °C at the rate of 10 mW/°C.

## recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|
| Supply voltage, $V_{CC}$ | 4.75 | 5 | 5.25 | V |
| Common-mode voltage at RXI inputs, $V_{IC}$ | 1 | | 4.2 | V |
| Differential voltage between RXI inputs, $V_{ID}$ | ±318 | | ±1315 | mV |
| High-level input voltage, $\overline{\text{LOOP}}$ and TXEN, $V_{IH}$ | 2 | | | V |
| Low-level input voltage, $\overline{\text{LOOP}}$ and TXEN, $V_{IL}$ | | | 0.8 | V |
| High-level output current, RXO and RXEN, $I_{OH}$ | | | −0.4 | mA |
| Low-level output voltage, RXO and RXEN, $I_{OL}$ | | | 16 | mA |
| Setup time, Driver mode, TXEN high before TXI↓, $t_{su1}$ (see Figure 8) | 10 | | | ns |
| Setup time, Loop mode, $\overline{\text{LOOP}}$ low before TXEN↑, $t_{su2}$ (see Figure 10) | 15 | | | ns |
| Setup time, Loop mode, TXEN high before TXI↓, $t_{su3}$ (see Figure 10) | 10 | | | ns |
| Hold time, Loop mode, TXEN high after TXI↑, $t_{h1}$ (see Figure 9) | 10 | | | ns |
| Hold time, Loop mode, $\overline{\text{LOOP}}$ low after TXEN↓, $th_2$ (see Figure 9) | 15 | | | ns |
| Operating free-air temperature, $T_A$ | 0 | | 70 | °C |

## electrical characteristics over recommended ranges of operating free-air temperature and supply voltage (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | | MIN | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $V_{IK}$ | Clamp voltage at all inputs | | $I_I = -18$ mA | | | −1.5 | V |
| $V_T$ | Driver input (TXI) threshold voltage | | $T_A = 0°C$ | $V_{CC} = 4.75$ V | 3.202 | 3.752 | V |
| | | | | $V_{CC} = 5$ V | 3.389 | 3.998 | |
| | | | | $V_{CC} = 5.25$ V | 3.577 | 4.244 | |
| | | | $T_A = 25°C$ | $V_{CC} = 4.75$ V | 3.213 | 3.797 | V |
| | | | | $V_{CC} = 5$ V | 3.400 | 4.043 | |
| | | | | $V_{CC} = 5.25$ V | 3.588 | 4.289 | |
| | | | $T_A = 70°C$ | $V_{CC} = 4.75$ V | 3.239 | 3.849 | V |
| | | | | $V_{CC} = 5$ V | 3.426 | 4.095 | |
| | | | | $V_{CC} = 5.25$ V | 3.614 | 4.341 | |
| $V_{IDT}$ | Receiver differential input threshold voltage | | | | | −275 | mV |
| $V_{OC}$ | Driver output (TXO) common-mode voltage | Idle | TXEN at 0.8 V, $\overline{\text{LOOP}}$1 at 2 V, $\overline{\text{LOOP}}$2 at 2 V, See Figure 1 | | 1 | 4.2 | V |
| | | Active | TXEN at 2 V, $\overline{\text{LOOP}}$1 at 2 V, $\overline{\text{LOOP}}$2 at 2 V, TXI at 3.2 V, See Figure 1 | | 1 | 4.2 | |
| | | Active | TXEN at 2 V, $\overline{\text{LOOP}}$1 at 2 V, $\overline{\text{LOOP}}$2 at 2 V, TXI at 4.4 V, See Figure 1 | | 1 | 4.2 | |
| $V_{OD}$ | Driver output (TXO) differential voltage | Idle | TXEN at 0.8 V, $\overline{\text{LOOP}}$1 at 2 V, $\overline{\text{LOOP}}$2 at 2 V, See Figure 1 | | | ±40 | mV |
| | | Active | TXEN at 2 V, $\overline{\text{LOOP}}$1 at 2 V, $\overline{\text{LOOP}}$2 at 2 V, TXI at 3.2 V, See Figure 1 | | −600 | −1315 | |
| | | Active | TXEN at 2 V, $\overline{\text{LOOP}}$1 at 2 V, $\overline{\text{LOOP}}$2 at 2 V, TXI at 4.4 V, See Figure 1 | | 600 | 1315 | |
| $V_{OH}$ | High-level output voltage | RXO, RXEN | $I_{OH} = -0.4$ mA | | 2.4 | | V |
| $V_{OL}$ | Low-level output voltage | RXO, RXEN | $I_{OL} = 16$ mA | | | 0.5 | V |
| $I_{IH}$ | High-level input current | TXEN, $\overline{\text{LOOP}}$ | $V_I = 2$ V | | | 20 | μA |
| | | TXI | $V_I = 4.5$ V | | | 400 | |
| | | $\overline{\text{RXI}}$, RXI | $V_{ID} = -0.5$ V, $V_{IC} = 1$ V to 4.2 V | | | 1000 | |
| $I_{IL}$ | Low-level input current | TXEN, $\overline{\text{LOOP}}$ | $V_I = 0.8$ V | | | −200 | μA |
| | | TXI | $V_I = 3.1$ V | | | 100 | |
| | | | $V_I = 0.3$ V | | 4 | 10 | |
| | | $\overline{\text{RXI}}$, RXI | $V_{ID} = 0.5$ V, $V_{IC} = 1$ V to 4.2 V | | | 1000 | |
| $I_{OD}$ | Driver differential output current | Idle | TXEN at 0.8 V, $\overline{\text{LOOP}}$1 at 2 V, $\overline{\text{LOOP}}$2 at 2 V, See Figure 2 | | | ±4 | mA |
| $I_{OS}$ | Short-circuit output current† | RXO, RXEN | $V_O$ at 0 V, $\overline{\text{RXI}}$ at 3 V, RXI at 2 V | | −40 | −150 | mA |
| $I_{CC}$ | Supply current | | $\overline{\text{LOOP}}$ at 2 V, TXEN at 2 V, TXI at 4.5 V, Outputs open | | | 225 | mA |

†Not more than one output should be shorted at a time, and the duration of the test should not exceed 1 second.

## electrical characteristics over recommended ranges of operating free-air temperature and supply voltage (unless otherwise noted) (continued)

| PARAMETER | TEST CONDITIONS† | MIN | MAX | UNIT |
|---|---|---|---|---|
| Driver fault condition current | TXO shorted to $\overline{\text{TXO}}$,<br>Current measured in short | | 150 | mA |
| | TXO at 0 V, $\overline{\text{TXO}}$ is open,<br>Current measured at TXO | | 150 | |
| | TXO is open, $\overline{\text{TXO}}$ at 0,<br>Current measured at $\overline{\text{TXO}}$ | | 150 | |
| | TXO at 0 V, $\overline{\text{TXO}}$ at 0 V,<br>Current measured at TXO and $\overline{\text{TXO}}$ | | 150 | |
| | TXO at 16 V, $\overline{\text{TXO}}$ is open,<br>Current measured at TXO | | 150 | |
| | TXO is open, $\overline{\text{TXO}}$ at 16 V,<br>Current measured at TXO | | 150 | |
| | TXO at 16 V, $\overline{\text{TXO}}$ at 16 V,<br>Current measured at TXO and $\overline{\text{TXO}}$ | | 150 | |
| Receiver fault condition current | RXI shorted to $\overline{\text{RXI}}$,<br>Current measured in short | | 10 | mA |
| | RXI at 0 V, $\overline{\text{RXI}}$ is open,<br>Current measured at RXI | | 3 | |
| | RXI is open, $\overline{\text{RXI}}$ at 0 V,<br>Current measured at RXI | | 3 | |
| | RXI at 0 V, $\overline{\text{RXI}}$ at 0 V,<br>Current measured at RXI and $\overline{\text{RXI}}$ | | 3 | |
| | RXI at 16 V, $\overline{\text{RXI}}$ at open,<br>Current measured at RXI | | 10 | |
| | RXI at open, $\overline{\text{RXI}}$ at 16 V,<br>Current measured at $\overline{\text{RXI}}$ | | 10 | |
| | RXI at 16 V, $\overline{\text{RXI}}$ at 16 V,<br>Current measured at RXI and $\overline{\text{RXI}}$ | | 10 | |

†Fault conditions should be measured on only one channel at a time.

## switching characteristics over recommended ranges of operating free-air temperature and $V_{CC}$ (unless otherwise noted)

### driver

| | PARAMETER | FROM (INPUT) | TO (OUTPUT) | TEST CONDITIONS | MIN | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $t_{PLH}$ | Propagation delay time, low-to-high level output | TXI | TXO, $\overline{TXO}$ | TXEN at 2 V, See Figure 3 | | 15 | ns |
| $t_{PHL}$ | Propagation delay time, high-to-low level output | TXI | TXO, $\overline{TXO}$ | TXEN at 2 V, See Figure 3 | | 15 | ns |
| $t_{PIL}$ | Propagation delay time, idle-to-low level output | TXI | TXO, $\overline{TXO}$ | TXEN at 2 V, See Figure 4 | | 25 | ns |
| $t_{PIL}$ | Propagation delay time, idle-to-low level output | TXEN | TXO, $\overline{TXO}$ | TXI at 3.2 V, See Figure 5 | | 25 | ns |
| $t_{PH70}$ | Propagation delay time, high-to-70% level output | TXI | TXO, $\overline{TXO}$ | TXEN at 2 V, See Figure 6 | 200 | | ns |
| | | TXEN | TXO, $\overline{TXO}$ | TXI at 4.4 V, See Figure 7 | 200 | | |
| $t_{PHI}$ | Propagation delay time, high-to-idle output | TXI | TXO, $\overline{TXO}$ | TXEN at 2 V, See Figure 6 | 200 | 8000 | ns |
| | | TXEN | TXO, $\overline{TXO}$ | TXI at 4.4 V, See Figure 7 | 200 | 8000 | |
| $V_U$ | Driver output differential undershoot | TXI | TXO, $\overline{TXO}$ | TXEN at 2 V, See Figure 6 | | −100 | mV |
| $t_{skew}$ | Driver caused signal skew ($t_{PLH} - t_{PHL}$) | TXI | TXO, $\overline{TXO}$ | TXEN at 2 V, See Figure 3 | | ±3 | ns |
| $t_r$ | Rise time, TXO, $\overline{TXO}$ | | | TXEN at 2 V, See Figure 3 | 1 | 5 | ns |
| $t_f$ | Fall time, TXO, $\overline{TXO}$ | | | TXEN at 2 V, See Figure 3 | 1 | 5 | ns |

### receiver

| | PARAMETER | FROM (INPUT) | TO (OUTPUT) | TEST CONDITIONS | MIN | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $t_{PLH}$ | Propagation delay time, low-to-high level output | $\overline{RXI}$, RXI | RXO | $V_{IC}$ = 1 V to 4.2 V, See Figure 11 | | 15 | ns |
| $t_{PHL}$ | Progagation delay time, high-to-low level output | $\overline{RXI}$, RXI | RXO | $V_{IC}$ = 1 V to 4.2 V, See Figure 11 | | 15 | ns |
| $t_{PLH}$ | Start-up delay time, low-to-high level output | $\overline{RXI}$, RXI | RXEN | $V_{IC}$ = 1 V to 4.2 V, $V_{ID}$ = −500 mV, See Figure 13 | | 50 | ns |
| $t_{PHL}$ | Shutdown delay time, high-to-low level output | $\overline{RXI}$, RXI | RXEN | $V_{IC}$ = 1 V to 4.2 V, $V_{ID}$ = 500 mV, See Figure 13 | 130 | 175 | ns |
| $t_{skew}$ | Receiver caused signal skew ($t_{PLH} - t_{PHL}$) | $\overline{RXI}$, RXI | RXO | $V_{IC}$ = 1 V to 4.2 V, $V_{ID}$ = 500 mV, See Figure 11 | | ±3 | ns |
| $t_w$ | Pulse duration at $\overline{RXI}$ and RXI (to not activate squelch) | | | $V_{IC}$ = 1 V to 4.2 V, $V_{ID}$ = −175 mV, See Figure 12 | 25 | | ns |
| $t_w$ | Pulse duration at $\overline{RXI}$ and RXI (to activate squelch) | | | $V_{IC}$ = 1 V to 4.2 V, $V_{ID}$ = −275 mV, See Figure 12 | | 50 | ns |
| $t_{r1}$ | Rise time, RXO | | | $V_{IC}$ = 1 V to 4.2 V, $V_{ID}$ = ±500 mV, See Figure 11 | 1 | 8 | ns |
| $t_{r2}$ | Rise time, RXEN | | | $V_{IC}$ = 1 V to 4.2 V, $V_{ID}$ = ±500 mV, See Figure 13 | 1 | 8 | ns |
| $t_{f1}$ | Fall time, RXO | | | $V_{IC}$ = 1 V to 4.2 V, $V_{ID}$ = ±500 mV, See Figure 11 | 1 | 8 | ns |
| $t_{f2}$ | Fall time, RXEN | | | $V_{IC}$ = 2.5 V, $V_{ID}$ = ±500 mV, See Figure 13 | 1 | 8 | ns |
| $t_{valid}$ | RXO valid after RXEN high | | | See Figure 11 | −10 | 15 | ns |

## switching characteristics over recommended ranges of operating free-air temperature and $V_{CC}$ (unless otherwise noted)

### loop

| PARAMETER | | FROM (INPUT) | TO (OUTPUT) | TEST CONDITIONS | MIN | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $t_{PLH}$ | Propagation delay time, low-to-high level output | TXI | RXO | LOOP at 0.8 V, TXEN at 2 V, See Figure 14 | | 30 | ns |
| $t_{PHL}$ | Propagation delay time, high-to-low level output | TXI | RXO | LOOP at 0.8 V, TXEN at 2 V, See Figure 14 | | 30 | ns |
| $t_{PLH}$ | Propagation delay time, low-to-high level output | TXEN | RXEN | LOOP at 0.8 V, See Figure 15 | | 50 | ns |
| $t_{PHL}$ | Propagation delay time, high-to-low level output | TXEN | RXEN | LOOP at 0.8 V, See Figure 15 | | 50 | ns |

## PARAMETER MEASUREMENT INFORMATION

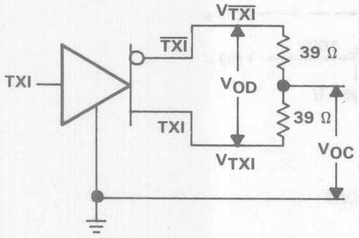


FIGURE 1

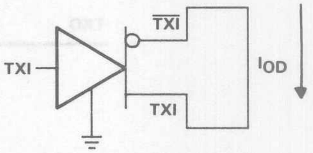
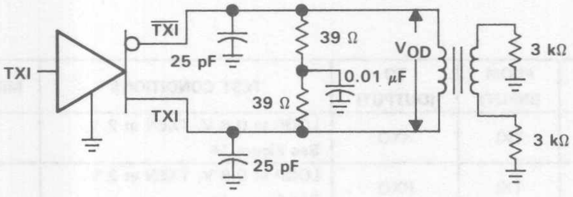
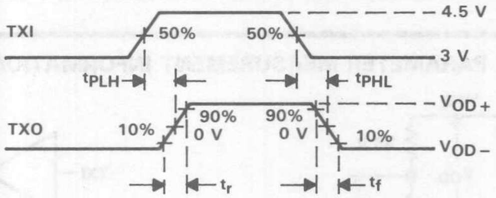


FIGURE 2

## PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



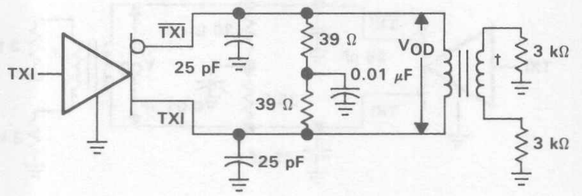
VOLTAGE WAVEFORMS

TRANSFORMER SPECIFICATIONS

| | |
|---|---|
| Turns Ratio | 1:1 |
| Magnetizing Inductance | 26 to 30 μH |
| Winding Resistance | 0.6 Ω Max |
| Rise Time 10% to 90% | 5 ns Max |
| Interwinding Capacitance | 25 pF |
| Leakage Inductance | 0.25 μH Max |
| Inductive Q | 1250 Min |

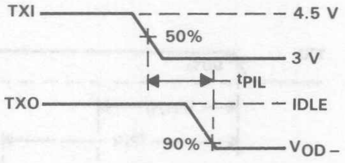
FIGURE 3

## PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

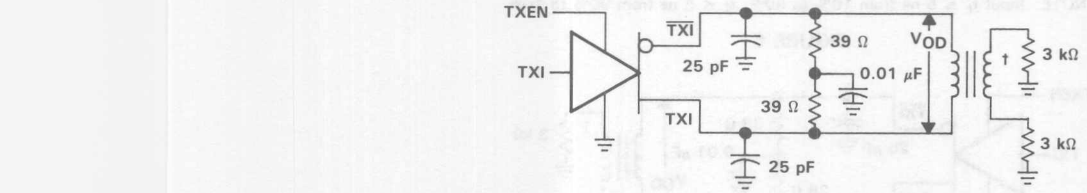
†See Figure 3



VOLTAGE WAVEFORMS

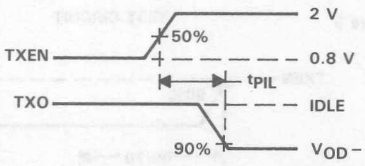
NOTE: Input $t_r \le 5$ ns from 10% to 90%; $t_f \le 5$ ns from 90% to 10%

FIGURE 4



TEST CIRCUIT

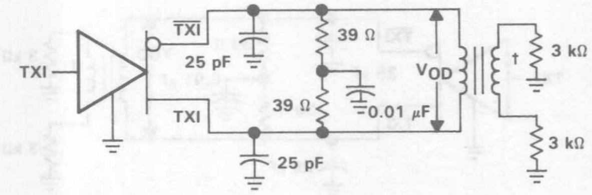
†See Figure 3



VOLTAGE WAVEFORMS

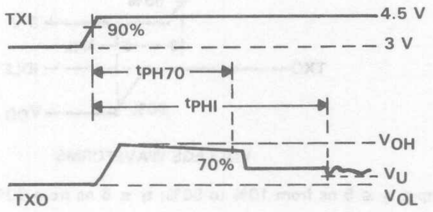
FIGURE 5

## PARAMETER MEASUREMENT INFORMATION



†See Figure 3

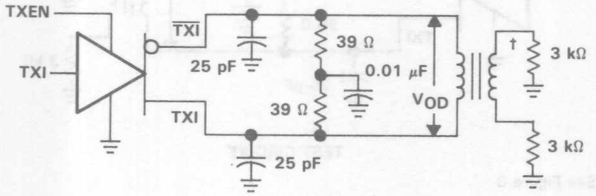
TEST CIRCUIT



VOLTAGE WAVEFORMS

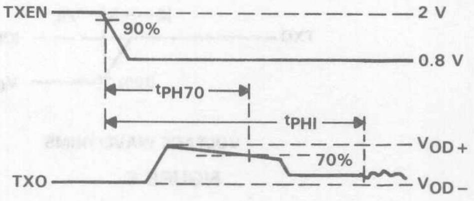
NOTE: Input $t_r \leq 5$ ns from 10% to 90%; $t_f \leq 5$ ns from 90% to 10%

FIGURE 6



†See Figure 3

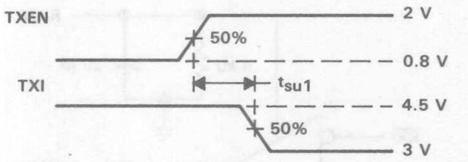
TEST CIRCUIT



VOLTAGE WAVEFORMS

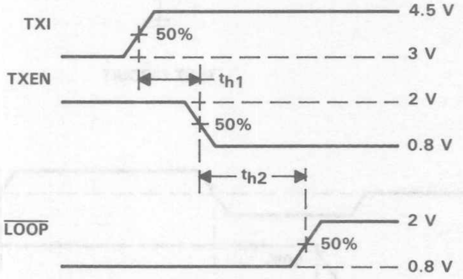
FIGURE 7

## PARAMETER MEASUREMENT INFORMATION



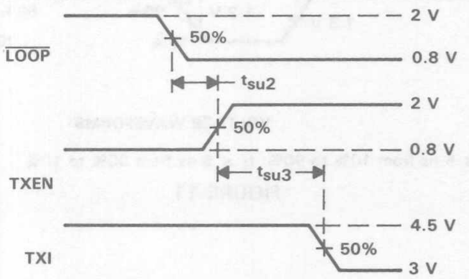
NOTE: Input $t_r \le 5$ ns from 10% to 90%; $t_f \le 5$ ns from 90% to 10%

FIGURE 8



NOTE: Input $t_r \le 5$ ns from 10% to 90%; $t_f \le 5$ ns from 90% to 10%

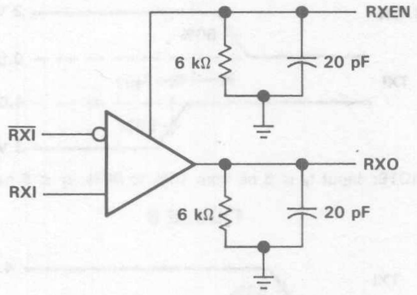
FIGURE 9



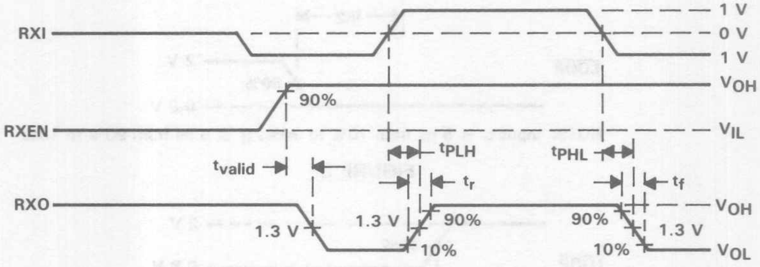
NOTE: Input $t_r \le 5$ ns from 10% to 90%; $t_f \le 5$ ns from 90% to 10%

FIGURE 10

## PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

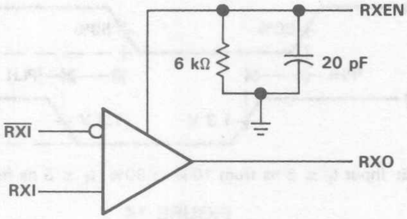


VOLTAGE WAVEFORMS

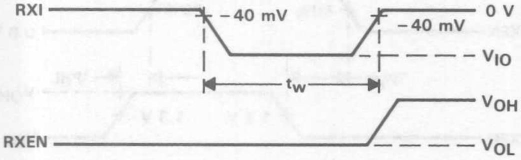
NOTE: Input $t_r \leq 5$ ns from 10% to 90%; $t_f \leq 5$ ns from 90% to 10%

FIGURE 11

## PARAMETER MEASUREMENT INFORMATION

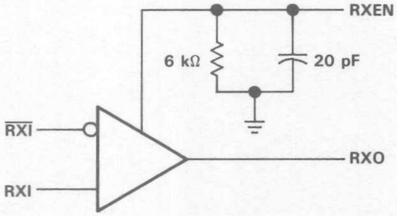


TEST CIRCUIT

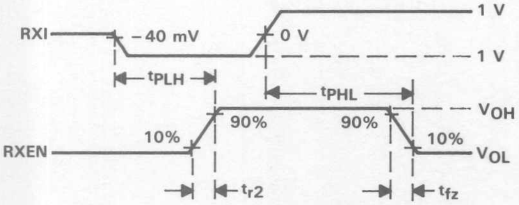


VOLTAGE WAVEFORMS

FIGURE 12



TEST CIRCUIT

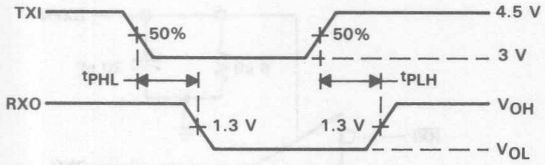


VOLTAGE WAVEFORMS

NOTE: Input $t_r \le 5$ ns from 10% to 90%; $t_f \le 5$ ns from 90% to 10%

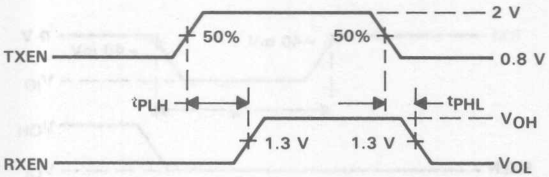
FIGURE 13

## PARAMETER MEASUREMENT INFORMATION



NOTE: Input $t_r \leq 5$ ns from 10% to 90%; $t_f \leq 5$ ns from 90% to 10%

FIGURE 14



NOTE: Input $t_r \leq 5$ ns from 10% to 90%; $t_f \leq 5$ ns from 90% to 10%

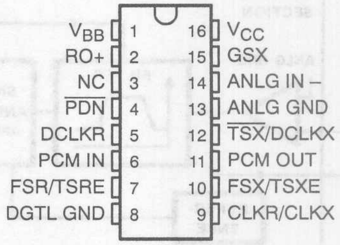
FIGURE 15

# TCM29C26
# LOW-POWER VARIABLE-FREQUENCY PCM OR DSP INTERFACE

D3567, JULY 1990–REVISED JANUARY 1991

- **Combined ADC, DAC, and Filters**
- **Extended Variable Frequency Operation:**
  - **Master Clock Up to 4.096 MHz**
  - **Sample Rates Up to 16 kHz**
  - **Passband Up to 6 kHz**
- **Reliability Silicon-Gate CMOS Technology**
- **Low Power Consumption:**
  - **Operating Mode . . . 40 mW Typ**
  - **Power-Down Mode . . . 5 mW Typ**
- **Excellent Power Supply Rejection Ratio Over Frequency Range of 0 to 50 kHz**
- **No External Components Needed for Sample, Hold, and Auto-Zero Functions**
- **Precision Internal Voltage References**
- **μ-law and A-law Coding**

**DW OR N PACKAGE**
**(TOP VIEW)**



NC–No internal connection

## description

The TCM29C26 is a single-chip pulse-code-modulated encoder and decoder (PCM codec) and PCM line filter. This device provides all the functions required to interface a full-duplex (4-wire) voice telephone circuit with a time-division-multiplexed (TDM) system. Primary applications of the device include digital encryption systems, digital voice-band data storage systems, digital signal processing, and mobile telephones.

The device is designed to perform the transmit encoding (A/D conversion) and receive decoding (D/A conversion) as well as the transmit and receive filtering functions in a pulse-code-modulated system.

The TCM29C26 provides the bandpass filtering of the analog signals prior to encoding and after decoding. This combination device performs the encoding and decoding of voice and call progress tones as well as the signaling supervision information.

The TCM29C26 is characterized for operation from 0°C to 70°C.

Caution. This device has limited built-in gate protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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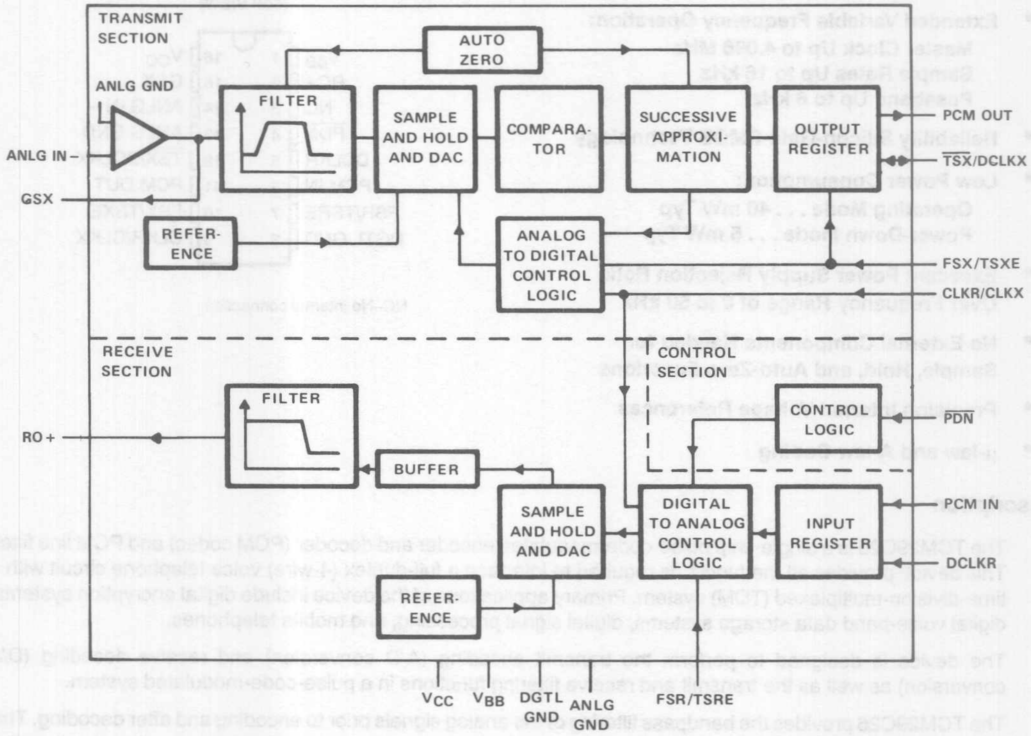
## functional block diagram



## Terminal Functions

| PIN NAME | PIN NO. | DESCRIPTION |
|---|---|---|
| ANLG GND | 13 | Analog ground return for all internal voice circuits. Not internally connected to DGTL GND. |
| ANLG IN– | 14 | Inverting analog input to uncommitted transmit operational amplifier. |
| CLKR/CLKX | 9 | Receive master clock and data clock for the fixed-data-rate mode. Receive master clock only for variable-data-rate mode. CLKR and CLKX are internally connected together.<br>Transmit master clock and data clock for the fixed-data-rate mode. Transmit master clock only for variable-data-rate mode. CLKR and CLKX are internally connected. |
| DCLKR | 5 | Selects fixed or variable data-rate operation. When this pin is connected to $V_{BB}$, the device operates in the fixed-data-rate mode. When DCLKR is not connected to $V_{BB}$, the device operates in the variable-data-rate mode, and DCLKR becomes the receive data clock, which operates at frequencies from 64 kHz to 4.096 MHz. |
| DGTL GND | 8 | Digital ground for all internal logic circuits. Not internally connected to ANLG GND. |
| FSR/TSRE | 7 | Frame synchronization clock input/time slot enable for receive channel. In the fixed-data-rate mode, FSR distinguishes between signaling and nonsignaling frames by a double- or single-length pulse, respectively. In the variable-data-rate mode, this signal must remain high for the duration of the time slot. The receive channel enters the standby state when FSR is TTL low for 300 ms. |
| FSX/TSXE | 10 | Frame synchronization clock input/time-slot enable for transmit channel. Operates independently of, but in an analogous manNer to, FSR/TSRE. The transmit channel enters the standby state when FSX is low for 300 ms. |
| GSX | 15 | Output terminal of internal uncommitted operational amplifier. Internally, this is the voice signal input to the transmit filter. |
| PCM IN | 6 | Receive PCM input. PCM data is clocked in on this pin on eight consecutive negative transitions of the receive data clock, which is CLKR in fixed-data-rate timing and DCLKR in variable-data-rate timing. |
| PCM OUT | 11 | Transmit PCM output. PCM data is clocked out on this output on eight consecutive positive transitions of the transmit data clock, which is CLKX in fixed-data-rate timing and DCLKX in variable-data-rate timing. |
| $\overline{\text{PDN}}$ | 4 | Power-down select. The device is inactive with a TTL low-level input to this pin and active with a TTL high-level input to this pin. |
| RO+ | 2 | Noninverting output of power amplifier. Can directly drive transformer hybrids or high-impedance loads in either a differential or a single-ended configuration. |
| $\overline{\text{TSX}}$/DCLKX | 12 | Transmit channel time slot strobe (output) or data clock (input) for the transmit channel. In the fixed-data-rate mode, this pin is an open-rain output to be used as an enable signal for a three-state buffer. In the variable-data rate mode, DCLKX becomes the transmit data clock, which operates at TTL levels from 64 kHz to 4.096 MHz. |
| $V_{BB}$ | 1 | Most negative supply voltage; input is – 5 V ± 5%. |
| $V_{CC}$ | 16 | Most positive supply voltage, input is 5 V ± 5%. |

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|---|
| Supply voltage, $V_{CC}$ (see Note 1) | – 0..3 V to 15 V |
| Output voltage, $V_O$ | – 0.3 V to 15 V |
| Input voltage, $V_I$ | – 0.3 V to 15 V |
| Digital ground voltage | – 0.3 V to 15 V |
| Operating free-air temperature range | 0°C to 70°C |
| Storage temperature range | – 65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: Voltage values for maximum ratings are with respect to $V_{BB}$.

## recommended operating conditions (see Note 2)

| | | | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|---|---|
| $V_{CC}$ | Supply voltage (see Note 3) | | 4.75 | 5 | 5.25 | V |
| $V_{BB}$ | Supply voltage | | – 4.75 | – 5 | – 5.25 | V |
| | DGTL GND voltage with respect to ANLG GND | | | 0 | | V |
| $V_{IH}$ | High-level input voltage | | 2.2 | | | V |
| $V_{IL}$ | Low-level input voltage | | | | 0.8 | V |
| $R_L$ | Load resistance | At RO+ | 10 | | | kΩ |
| $C_L$ | Load capacitance | At RO+ | | | 10 | pF |
| $T_A$ | Operating free-air temperature | TCM29C26 | 0 | | 70 | °C |

NOTES: 2. To avoid any possible damage and reliability problems to these CMOS devices when applying power, the following sequence should be followed:

(1) Connect ground
(2) Connect the most negative voltage
(3) Connect the most positive voltage
(4) Connect the input signals

When powering down the device, follow the above steps in reverse order. If the above procedure cannot be followed, connect a diode between $V_{BB}$ and digital ground, cathode to DGND, anode to $V_{BB}$.

3. Voltages at analog inputs and outputs, $V_{CC}$, and $V_{BB}$ terminals are with respect to the ANLG GND terminal. All other voltages are referenced to the DGTL GND terminal unless otherwise noted.

## electrical characteristics over recommended operating free-air temperature range (unless otherwise noted)

### supply current, $f_{DCLK}$ = 4.096 MHz, outputs not loaded

| PARAMETER | | | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $I_{CC}$ | Supply current from $V_{CC}$ | Operating | | | 4 | 6 | mA |
| | | Standby | FSX or FSR at $V_{IL}$ after 300 ms | | 0.5 | 0.8 | |
| | | Power-down | $\overline{PDN}$ $V_{IL}$ after 10 µs | | 0.3 | 0.8 | |
| $I_{BB}$ | Supply current from $V_{BB}$ | Operating | | | – 4 | – 6 | mA |
| | | Standby | FSX or FSR at $V_{IL}$ after 300 ms | | – 0.5 | 0.8 | |
| | | Power-down | $\overline{PDN}$ $V_{IL}$ after 10 µs | | – 0.3 | – 0.8 | |
| | Power dissipation | Operating | | | 40 | 60 | mW |
| | | Standby | FSX or FSR at $V_{IL}$ after 300 ms | | 5 | 8 | |
| | | Power-down | $\overline{PDN}$ $V_{IL}$ after 10 µs | | 3 | 8 | |

### digital interface

| PARAMETER | | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|---|---|---|---|---|---|---|
| $V_{OH}$ | High-level output vovltage at PCM out | $I_{OH}$ = – 9.6 mA | 2.4 | | | V |
| $V_{OL}$ | Low-level output voltage at PCM out, TSX | $I_{OL}$ = 3.2 mA | | | 0.4 | V |
| $I_{IH}$ | High-level input current, any digital input | $V_I$ = 2.2 V to $V_{CC}$ | | | 10 | µA |
| $I_{IL}$ | Low-level input current, any digital input | $V_I$ = 0 to 0.8 V | | | 10 | µA |
| $C_i$ | Input capacitance | | | 5 | 10 | pF |
| $C_o$ | Output capacitance | | | 5 | | pF |

### transmit amplifier input

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|---|---|---|---|---|---|
| Input current at ANLG IN – | $V_I$ = 2.17 V to 2.17 V | | | ± 200 | nA |
| Input offset voltage at ANLG IN – | $V_I$ = 2.17 V to 2.17 V | | | ± 25 | mV |
| Common-mode rejection at ANLG IN – | $V_I$ = 2.17 V to 2.17 V | 55 | | | dB |
| Open-loop voltage amplification at GSX | | 5000 | | | |
| Open-loop unity-gain bandwidth at GSX | | | 1 | | MHz |
| Input resistance at ANLG IN – | | 10 | | | MΩ |

### receive filter output

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|---|---|---|---|---|---|
| Output offset voltage RO+ (single-ended) | Relative to ANLG GND | | 40 | | mV |
| Output resistance at RO+ | | | 10 | | Ω |

† All typical values are at $V_{BB}$ = – 5 V, $V_{CC}$ = 5 V, $T_A$ = 25°C.

### gain and dynamic range, $V_{CC}$ = 5 V, $V_{BB}$ = – 5 V, $T_A$ = 25°C (unless otherwise noted) (see Notes 4 and 5)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| Encoder milliwatt response (transmit gain tolerance) | | Signal input = 1.064 V rms | | ± 0.5 | ± 1.0 | dBm0 |
| Encoder milliwatt response (nominal supplies and temperature) | | $T_A$ = 0°C to 70°C,<br>Supply voltage = 5 V ± 5% | | | ± 0.15 | dB |
| Digital milliwatt response (receive tolerance gain) relative to zero-transmission level point | | Output signal = 1 kHz | | ± 0.5 | ± 1.0 | dBm0 |
| Digital milliwatt response variation with temperature and supplies | | $T_A$ = 0°C to 70°C,<br>Supply voltages = 5 V ± 5% | | | ± 0.15 | dB |
| Zero-transmission-level point, transmit channel (0 dBm0) | μ-law | $R_L$ = 10 kΩ | | 2.76 | | dBm |
| Zero-transmission-level point, receive channel (0 dBm0) | μ-law | $R_L$ = 10 kΩ | | 5.76 | | dBm |

NOTES: 4. Unless otherwise noted, the analog input is a 0-dBm0, 1020-Hz sine wave, where 0 dBm0 is defined as the zero-reference point of the channel under test. This corresponds to an analog signal input of 1.064 V rms, or an output of 1.503 V rms.

5. The input amplifier is set for unity gain, noninverting. The digital input is a PCM bit stream generated by passing a 0-dBm0, 1020-Hz sine wave through an ideal encoder.

### gain tracking over recommended ranges of supply voltage and operating free-air temperature, reference level = – 10 dBm0

| PARAMETER | TEST CONDITIONS | MIN | MAX | UNIT |
|---|---|---|---|---|
| Transmit gain tracking error, sinusoidal input | 3 to – 40 dBm0 | | ± 0.5 | dB |
| | – 40 to – 50 dBm0 | | ± 1.5 | |
| Receive gain tracking error, sinusoidal input | 3 to – 40 dBm0 | | ± 0.5 | dB |
| | – 40 to – 50 dBm0 | | ± 1.5 | |

### noise over recommended ranges of supply voltage and operating free-air temperature

| PARAMETER | TEST CONDITIONS | MIN | MAX | UNIT |
|---|---|---|---|---|
| Transmit noise, C-message weighted | ANLG IN + = ANLG GND,<br>ANLG IN – = GSX | | 18 | dBrnC0 |
| Transmit noise, psophometrically weighted | ANLG IN + = ANLG GND,<br>ANLG IN – = GSX | | – 72 | dBm0p |
| Receive noise, C-message weighted quiet code | PCM IN = 11111111 (μ-law)<br>Measured at PWRO + | | 11 | dBrnC0 |
| Receive noise, psophometrically weighted | PCM = lowest positive decode level | | – 79 | dBm0p |

## power supply rejection and crosstalk attenuation over recommended ranges of supply voltage and operating free-air temperature

| | | | MIN | TYP† | MAX | UNIT |
|---|---|---|---|---|---|---|
| $V_{CC}$ supply voltage rejection ratio, transmit channel | f = 0 to 30 kHz | Idle channel, Supply signal = 200 mV p-p, f measured at PCM OUT | | −30 | | dB |
| | f = 30 to 50 kHz | | | −45 | | |
| $V_{BB}$ supply voltage rejection ratio, transmit channel | f = 0 to 30 kHz | Idle channel, Supply signal = 200 mV p-p, f measured at PCM OUT | | −30 | | dB |
| | f = 30 to 50 kHz | | | −55 | | |
| $V_{CC}$ supply voltage rejection ratio, receive channel (single-ended) | f = 0 to 30 kHz | Idle channel, Supply signal = 200 mV p-p, Narrow-band, f measured at PWRO + | | −20 | | dB |
| | f = 30 to 50 kHz | | | −45 | | |
| $V_{BB}$ supply voltage rejection ratio, receive channel (single-ended) | f = 0 to 30 kHz | Idle channel, Supply signal = 200 mV p-p, Narrow-band, f measured at PWRO + | | −20 | | dB |
| | f = 30 to 50 kHz | | | −45 | | |
| Crosstalk attenuation, transmit-to-receive (single-ended) | | ANLG IN + = 0 dBm0, f = 1.02 kHz, Unity gain, PCM IN = lowest decode level, Measured at PWRO + | 68 | | | dB |
| Crosstalk attenuation, receive-to-transmit (single-ended) | | PCM IN = 0 dBm0, f = 1.02 kHz, Measured at PCM OUT | 68 | | | dB |

† All typical values are at $V_{BB} = -5$ V, $V_{CC} = 5$ V, and $T_A = 25°C$.

## distortion over recommended ranges of supply voltage and operating free-air temperature

| PARAMETER | TEST CONDITIONS | MIN | MAX | UNIT |
|---|---|---|---|---|
| Transmit signal to distortion ratio, sinusoidal input | ANLG IN + = 0 to −30 dBm0 | 33 | | dB |
| | ANLG IN + = −30 to −40 dBm0 | 28 | | |
| | ANLG IN + = −40 to −45 dBm0 | 23 | | |
| Receive signal to distortion ratio, sinusoidal input | ANLG IN + = 0 to −30 dBm0 | 33 | | dB |
| | ANLG IN + = −30 to −40 dBm0 | 28 | | |
| | ANLG IN + = −40 to −45 dBm0 | 23 | | |
| Transmit single-frequency distortion products | AT&T Advisory #64 (3.8), Input signal = 0 dBm0 | | −40 | dBm0 |
| Receive single-frequency distortion products | AT&T Advisory #64 (3.8), Input signal = 0 dBm0 | | −40 | dBm0 |

## transmit filter transfer over recommended ranges of supply voltage and operating free-air temperature, CLK = 4.096 MHz, FSX/FSR = 16 kHz (see Figure 1)

| PARAMETER | TEST CONDITIONS | | MIN | MAX | UNIT |
|---|---|---|---|---|---|
| Gain relative to gain at 1.02 kHz | Input amplifier set for unity gain, Noninverting maximum gain output, Input signal at ANLG IN + is 0 dBm0 | 50 Hz | −10 | 0 | dB |
| | | 200 Hz | −1 | 0.5 | |
| | | 300 Hz to 6 kHz | −0.5 | 0.5 | |
| | | 6.5 kHz | −4 | 0.3 | |
| | | 6.8 kHz | −6 | 0 | |
| | | 8 kHz | | −12 | |
| | | 9 kHz and above | | −30 | |

### receive filter transfer over recommended ranges of supply voltage and operating free-air temperature (see Figure 2)

| PARAMETER | TEST CONDITIONS | | MIN | MAX | UNIT |
|---|---|---|---|---|---|
| Gain relative to gain at 1.02 kHz | Input signal at PCM IN is 0 dBm0 | Below 200 Hz | − 2 | 0.5 | dB |
| | | 200 Hz | − 1 | 0.5 | |
| | | 300 Hz to 6 kHz | − 0.5 | 0.5 | |
| | | 6.6 kHz | − 4 | 0.3 | |
| | | 6.8 kHz | − 6 | 0 | |
| | | 8 kHz | | − 12 | |
| | | 9.2 kHz and above | | − 30 | |

### clock timing requirements over recommended ranges of supply voltage and operating free-air temperature (see timing diagrams)

| PARAMETER | | MIN | TYP† | MAX | UNIT |
|---|---|---|---|---|---|
| $t_{c(CLK)}$ | Clock period for CLKX, CLKR (2.048-MHz systems) | 244 | | | ns |
| $t_r$, $t_f$ | Rise and fall times for CLKX and CLKR | 5 | | 20 | ns |
| $t_{w(CLK)}$ | Pulse duration for CLKX and CLKR (see Note 6) | 110 | | | ns |
| $t_{w(DCLK)}$ | Pulse duration for DCLK ($f_{DCLK}$ = 64 Hz to 2.048 MHz) (see Note 6) | 110 | | | ns |
| | Clock duty cycle [$t_{w(CLK)}/t_{c(CLK)}$] for CLKX and CLKR | 45% | 50% | 55% | |

† All typical values are at $V_{BB} = -5$ V, $V_{CC} = 5$ V, and $T_A = 25°C$.

NOTE 6: FSX CLK must be phase locked with the CLKX, FSR CLK must be phase locked with CLKR.

### transmit timing requirements over recommended ranges of supply voltage and operating free-air temperature, fixed-data-rate mode (see timing diagrams)

| PARAMETER | | MIN | MAX | UNIT |
|---|---|---|---|---|
| $t_{d(FSX)}$ | Frame sync delay time | 60 | $t_{c(CLK)} - 60$ | ns |

### propagation delay times over recommended ranges of operating conditions, fixed-data-rate mode (see timing diagrams)

| PARAMETER | | TEST CONDITIONS | MIN | MAX | UNIT |
|---|---|---|---|---|---|
| $t_{pd1}$ | From rising edge of transmit clock to Bit 1 data valid at PCM OUT (data enable time on time slot entry) (see Note 7) | $C_L$ = 0 to 100 pF | 0 | 90 | ns |
| $t_{pd2}$ | From rising edge of transmit clock Bit n to Bit n + 1 data valid at PCM OUT (data valid time) | $C_L$ = 0 to 100 pF | 0 | 90 | ns |
| $t_{pd3}$ | From falliing edge of transmit clock Bit 8 to Bit 8 Hi-Z at PCM OUT (data float time on time slot exit) (see Note 7) | $C_L$ = 0 | 60 | 215 | ns |
| $t_{pd4}$ | From rising edge of transmit clock Bit 1 to TSX active (low) (time slot enable time) | $C_L$ = 0 to 100 pF | 0 | 90 | ns |
| $t_{pd5}$ | From falling edge of transmit clock Bit 8 to TSX inactive (high) (time slot disable time) (see Note 7) | $C_L$ = 0 | 60 | 190 | ns |

NOTE 7: Timing parameters $t_{pd1}$, $t_{pd3}$, and $t_{pd5}$ are referenced to the high-impedance state.

### receive timing requirements over recommended ranges of supply voltage and operating free-air temperature, fixed-data-rate mode (see timing diagrams)

| PARAMETER | | MIN | MAX | UNIT |
|---|---|---|---|---|
| $t_{d(FSR)}$ | Frame sync delay time | 60 | $t_{c(CLK)} - 60$ | ns |

### transmit timing requirements over recommended ranges of supply voltage and operating free-air temperature, variable-data-rate mode (see timing diagrams)

| PARAMETER | | MIN | MAX | UNIT |
|---|---|---|---|---|
| $t_{d(TSDX)}$ | Time slot delay time from DCLKX | 60 | $t_{d(DCLKX)} - 60$ | ns |
| $t_{d(FSX)}$ | Frame sync delay time | 60 | $t_{c(DCLK)} - 60$ | ns |
| $t_{c(DCLKX)}$ | Clock period for DCLKX | 244 | 15620 | ns |

### propagation delay times over recommended ranges of operating conditions, variable-data-rate mode (see Note 8 and timing diagrams)

| PARAMETER | | TEST CONDITIONS | MIN | MAX | UNIT |
|---|---|---|---|---|---|
| $t_{pd7}$ | Data delay time from DCLKX | $C_L$ = 0 to 100 pF | 0 | 90 | ns |
| $t_{pd8}$ | Data delay from time slot enable to PCM OUT | $C_L$ = 0 to 100 pF | 0 | 50 | ns |
| $t_{pd9}$ | Data delay from time slot disable to PCM OUT | $C_L$ = 0 to 100 pF | 0 | 80 | ns |
| $t_{pd10}$ | Data delay time from FSX | $t_{d(TSDX)}$ = 80 ns | 0 | 90 | ns |

NOTE 8: Timing parameters $t_{pd8}$ and $t_{pd9}$ are referenced to a high-impedance state.

### receive timing requirements over recommended ranges of supply voltage and operating free-air temperature, variable-data-rate mode (see timing diagrams)

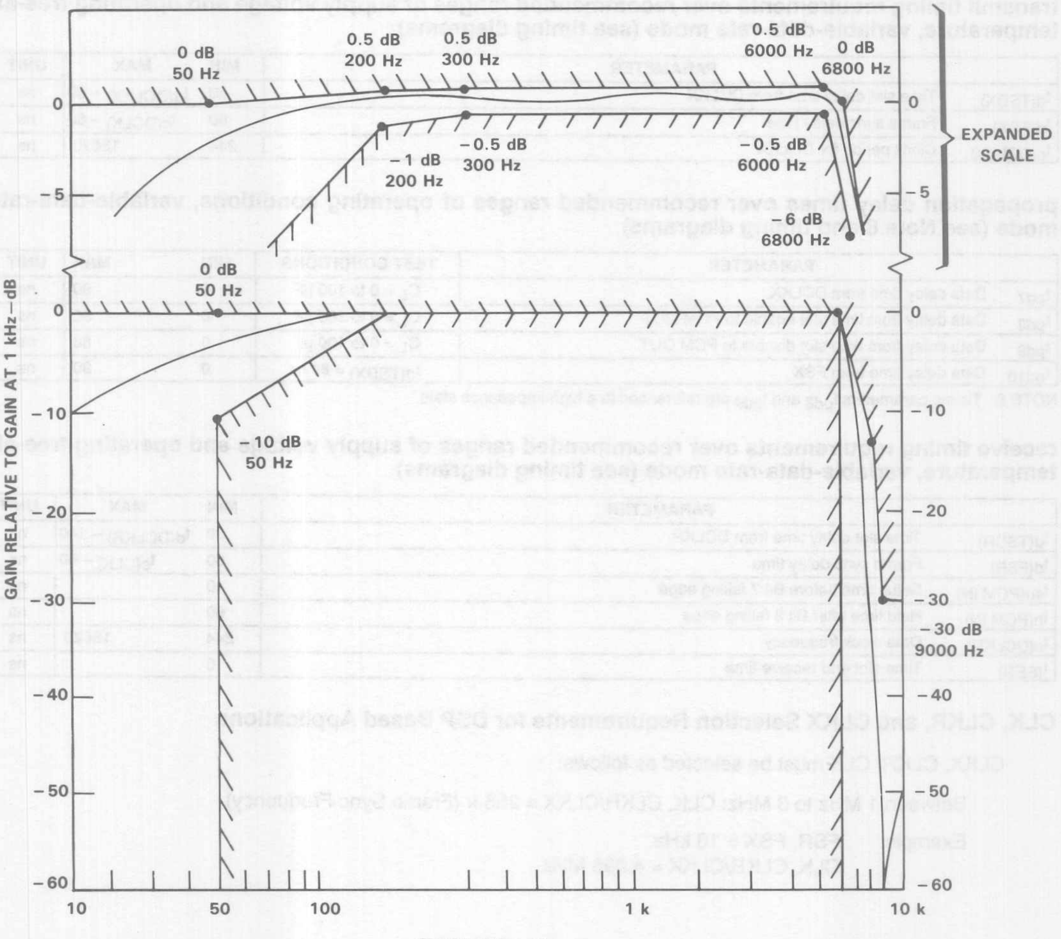
| PARAMETER | | MIN | MAX | UNIT |
|---|---|---|---|---|
| $t_{d(TSDR)}$ | Time slot delay time from DCLKR | 60 | $t_{d(DCLKR)} - 140$ | ns |
| $t_{d(FSR)}$ | Frame sync delay time | 60 | $t_{c(CLK)} - 60$ | ns |
| $t_{su(PCM IN)}$ | Setup time before Bit 7 falling edge | 10 | | ns |
| $t_{h(PCM IN)}$ | Hold time after Bit 8 falling edge | 60 | | ns |
| $t_{c(DCLKR)}$ | Data clock frequency | 244 | 15620 | ns |
| $t_{(SER)}$ | Time slot end receive time | 0 | | ns |

### CLK, CLKR, and CLKX Selection Requirements for DSP Based Applications

CLKX, CLKR, CLK must be selected as follows:

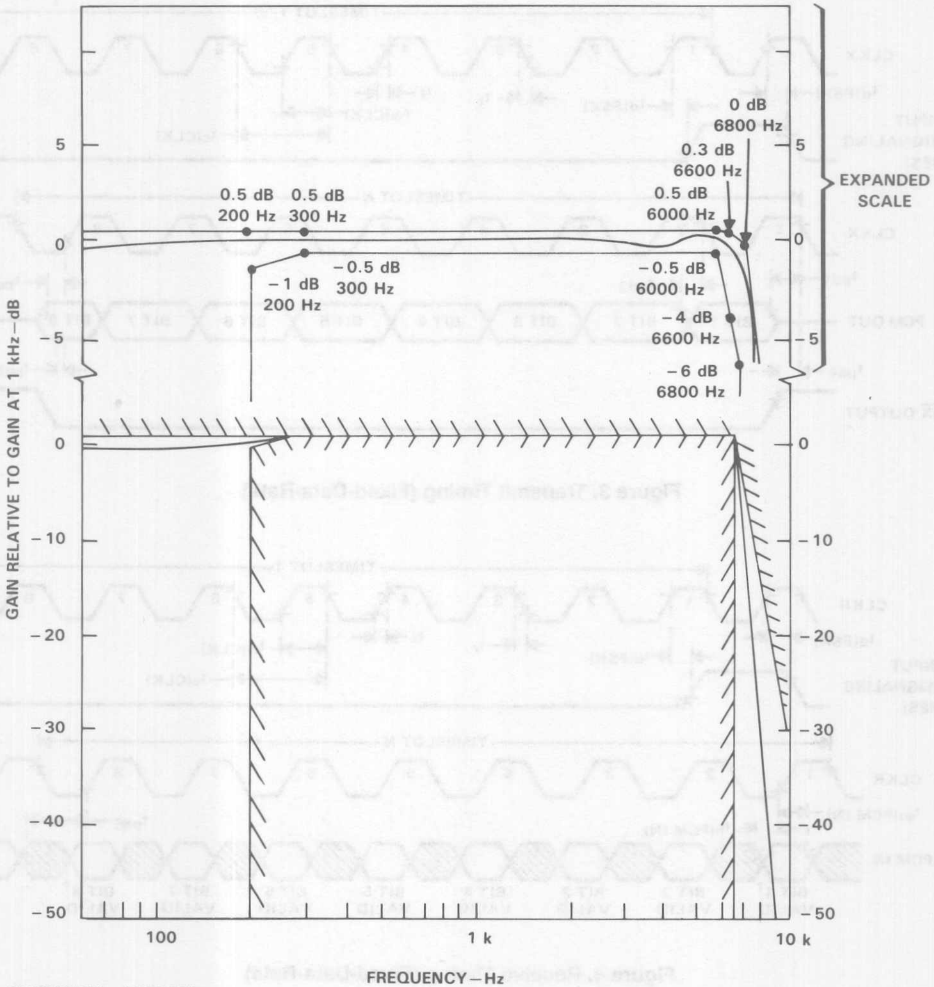
Between 1 MHz to 3 MHz: CLK, CLKR/CLKX = 256 × (Frame Sync Frequency)

Example: FSR, FSX = 16 kHz
CLK, CLKR/CLKX = 4.096 MHz



NOTE A: CLKR/CLKX = 4.096 MHz

Figure 1. Transfer Characteristics of the Transmit Filter



NOTE A: CLKR/CLKX = 4.096 MHz

Figure 2. Transfer Characteristics of the Receiver Filter

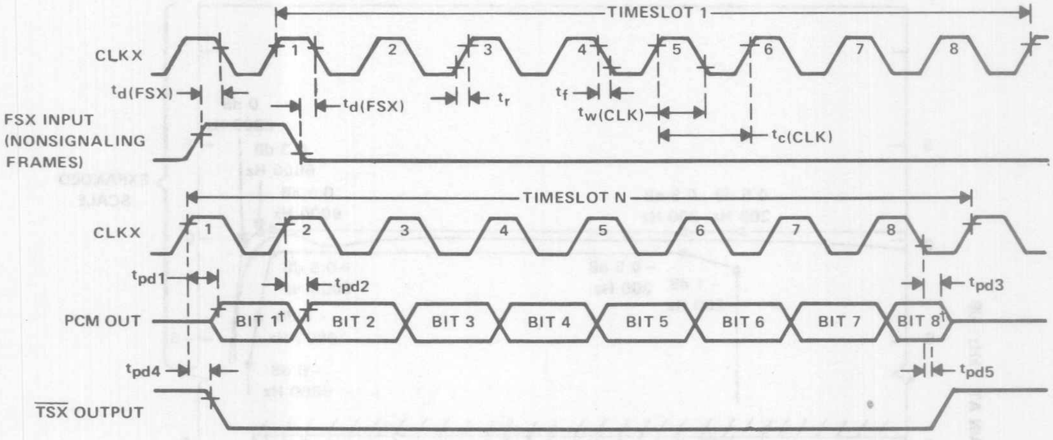


Figure 3. Transmit Timing (Fixed-Data-Rate)

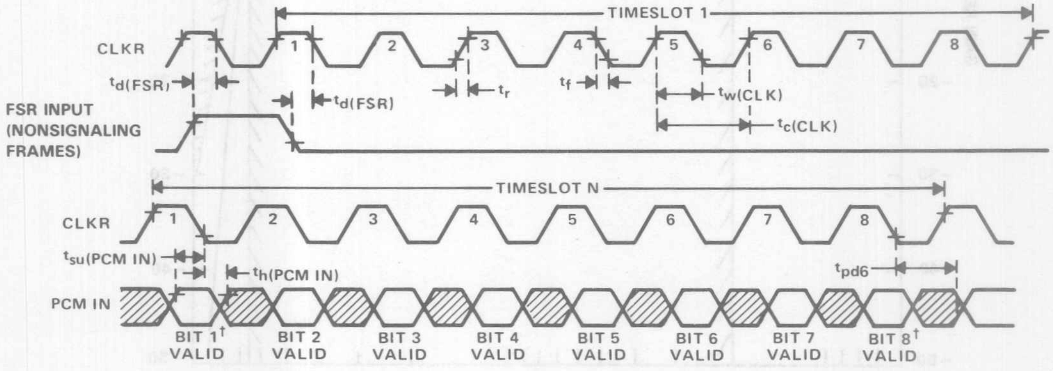


Figure 4. Receive Timing (Fixed-Data-Rate)

† Bit 1 = MSB = SIGN BIT and is clocked in first on the PCM-IN pin or clocked out first on the PCM-OUT pin. BIT 8 = LSB = LEAST SIGNIFICANT BIT and is clocked in last on the PCM-IN pin or is clocked out last on the PCM-OUT pin.

NOTE: Inputs are driven from 0.45 V to 2.4 V. Time intervals are referenced to 2 V if the high level is indicated and 0.8 V if the low level is indicated.

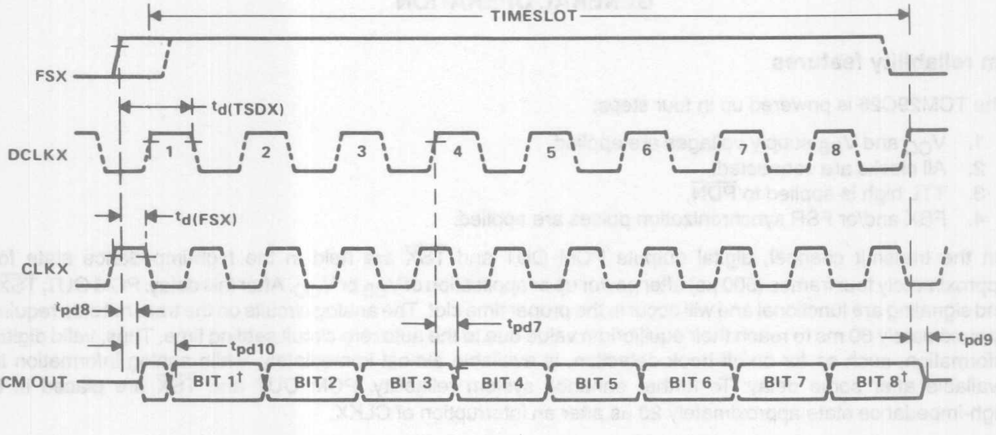


Figure 5. Transmit Timing (Variable-Data-Rate)

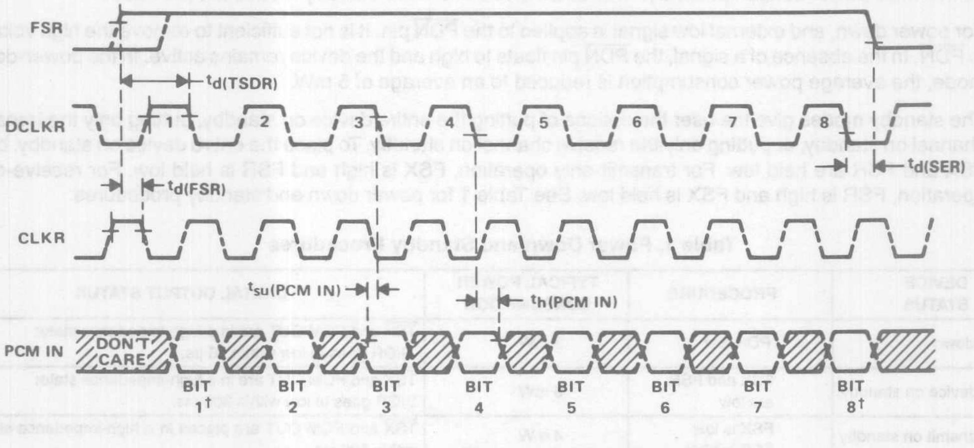


Figure 6. Receive Timing (Variable-Data-Rate)

† Bit 1 = MSB = SIGN BIT and is clocked in first on the PCM-IN pin or clocked out first on the PCM-OUT pin. BIT 8 = LSB = LEAST SIGNIFICANT BIT and is clocked in last on the PCM-IN pin or is clocked out last on the PCM-OUT pin.

NOTE: All timing parameters, referenced to $V_{IH}$ and $V_{IL}$ except $t_{pd8}$ and $t_{pd9}$, which reference a high-impedance state.

## GENERAL OPERATION

### system reliability features

The TCM29C26 is powered up in four steps:

1. $V_{CC}$ and $V_{BB}$ supply voltages are applied.
2. All clocks are connected.
3. TTL high is applied to $\overline{\mathrm{PDN}}$.
4. FSX and/or FSR synchronization pulses are applied.

On the transmit channel, digital outputs PCM OUT and $\overline{\mathrm{TSX}}$ are held in the high-impedance state for approximately four frames (500 μs) after power up or application of $V_{BB}$ or $V_{CC}$. After this delay, PCM OUT, $\overline{\mathrm{TSX}}$, and signaling are functional and will occur in the proper time slot. The analog circuits on the transmit side require approximately 60 ms to reach their equilibrium value due to the autozero circuit settling time. Thus, valid digital information, such as for on/off hook detection, is available almost immediately, while analog information is available after some delay. To further enhance system reliability, PCM OUT and $\overline{\mathrm{TSX}}$ are placed in a high-impedance state approximately 20 μs after an interruption of CLKX.

### power-down and standby operations

To minimize power consumption, a power-down mode and three standby modes are provided.

For power down, and external low signal is applied to the $\overline{\mathrm{PDN}}$ pin. It is not sufficient to remove the high voltage to $\overline{\mathrm{PDN}}$. In the absence of a signal, the $\overline{\mathrm{PDN}}$ pin floats to high and the device remains active. In the power-down mode, the average power consumption is reduced to an average of 5 mW.

The standby modes give the user the options of putting the entire device on standby, putting only the transmit channel on standby, or putting only the receive channel on standby. To place the entire device on standby, both FSX and FSR are held low. For transmit-only operation, FSX is high and FSR is held low. For receive-only operation, FSR is high and FSX is held low. See Table 1 for power down and standby procedures.

**Table 1. Power Down and Standby Procedures**

| DEVICE STATUS | PROCEDURE | TYPICAL POWER CONSUMPTION | DIGITAL OUTPUT STATUS |
|---|---|---|---|
| Power down | $\overline{\mathrm{PDN}}$ low | 3 mW | $\overline{\mathrm{TSX}}$ and PCM OUT are in a high-impedance state:<br>SIGR goes to low within 10 μs. |
| Entire device on standby | FSX and FSR are low | 5 mW | $\overline{\mathrm{TSX}}$ and PCM OUT are in a high-impedance state:<br>SIGR goes to low within 300 ms. |
| Only transmit on standby | FSX is low<br>FSR is high | 4 mW | $\overline{\mathrm{TSX}}$ and PCM OUT are placed in a high-impedance state within 300 ms. |
| Only receive on standby | FSR is low<br>FSX is high | 4 mW | SIGR is placed in a high-impedance state within 300 ms. |

### fixed-data-rate timing

Fixed-data-rate timing is selected by connecting DCLKR to $V_{BB}$. It uses master clocks CLKX and CLKR, frame synchronizer clocks FSX and FSR, and output $\overline{\mathrm{TSX}}$. FSX and FSR are inputs that set the sampling frequency. Data is transmitted on the PCM OUT pin on the first eight positive transitions of CLKX following the rising edge of FSX. Data is received on the PCM IN pin on the first eight falling edges of CLKR following FSR. A digital-to-analog (D/A) conversion is performed on the received digital word and the resulting analog sample is held on an internal sample-and-hold capacitor until transferred to the receive filter.

## variable data rate timing

Variable-data-rate timing is selected by connecting DCLKR to the bit clock for the receive PCM highway rather than to $V_{BB}$. It uses master clocks CLKX and CLKR, bit clocks DCLKX and DCLKR, and frame synchronization clocks FSX and FSR.

Variable-data-rate timing allows for a flexible data frequency. The frequency of the bit clocks can be varied from 64 kHz to 4.096 MHz. The bit clocks must be synchronous.

While the FSX/TSXE input is high, PCM data is transmitted from PCM OUT onto the highway on the next eight consecutive positive transitions of DCLKX. Similarly, while the FSR/TSRE input is high, the PCM word is received from the highway by PCM IN on the next eight consecutive negative transitions of DCLKR.

The transmitted PCM word is repeated in all remaining time slots in the frame as long as DCLKX is pulsed and FSX is held high. This feature, which allows the PCM word to be transmitted to the PCM highway more than once per frame, if desired, is available only with variable-data-rate timing. Signaling is allowed only in the fixed-data-rate mode because the variable-data-rate mode provides no means with which to specify a signaling frame.

## asynchronous operation

In order to avoid crosstalk problems associated with special interrupt circuits, the design includes separate digital-to-analog converters and voltage references on the transmit and receive sides to allow completely independsent operation of the two channels. In either timing mode, the master clock, data clock, and time slot strobe must be synchronized at the beginning of each frame. Specifically, in the variable-rate mode, the falling edge of CLKX must occur within $t_{d(FSX)}$ ns after the rise of FSX, and the falling edge of DCLKX must occur within $t_{dTSDX}$ ns after the rise of FSX. CLKX and DCLKX are synchronized once per frame but may be of different frequencies. The receive channel operates in a similar manner and is completely independent of the transmit timing (see variable data rate timing diagrams). This approach requires the provisioin of two separate master clocks but avoids the use of a synchronizer, which can cause intermittent data conversion errors.

## conversion laws

The TCM29C26 provides μ-law operations.

## transmit operation

### transmit filter

The input section provides gain adjustment in the passband by means of an on-chip uncommitted operational amplifier. The load impedance to ground (ANLG GND) at the amplifier output (GSX) must be greater than 10 kΩ in parallel with less than 50 pF. The input operational amplifier can also be used in the inverting mode or differential amplifier mode.

A low-pass antialiasing section is included on the device. This section provides 35-dB attenuation at the sampling frequency. No external components are required to provide the necessary antialiasing function for the switched capacitor section of the transmit filter.

### encoding

The encoder internally samples the output of the transmit filter and holds each sample on an internal sample and hold capacitor. The encoder performs an analog-to-digital conversion on a switched capacitor array. Digital data representing the sample is transmitted on the first eight data clocks bits of the next frame.

The autozero circuit corrects for dc offset on the input signal to the encoder using the sign bit averaging technique. The sign bit from the encoder output is long-term averaged and subtracted from the input to the encoder. All dc offset is removed from the encoder input waveform.

## receive operation

### decoding

The serial PCM word is received at the PCM IN pin on the first eight data clock bits of the frame. Digital-to-analog conversion is performed and the corresponding analog sample is held on an internal sample-and-hold capacitor. This sample is transferred to the receive filter.

### receive filter

The receive section of the filter provides passband flatness and stopband rejection that fulfills the AT&T D3/D4 specification. The filter contains the required compensation for the (sin x)/x response of such decoders.

## receive output power amplifiers

A balanced output amplifier is provided to allow maximum flexibility in output configuration. Either of the two outputs can be used single-ended (i.e., referenced to ANLG GND) to drive single-ended loads. Alternatively, the differential output will directly drive a bridged load. The output stage is capable of driving loads as low as 10 kΩ.

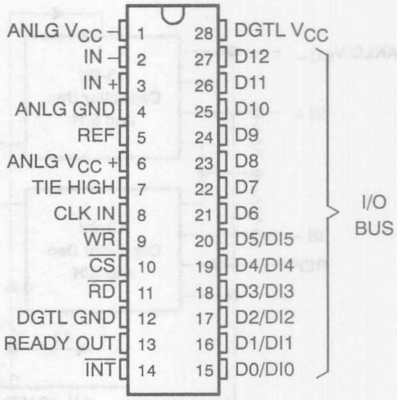
Transmission levels are specified relative to the receive channel output under digital milliwatt conditions.

# TLC1225
# SELF-CALIBRATING 12-BIT-PLUS-SIGN ANALOG-TO-DIGITAL CONVERTER

D3611, AUGUST 1990

- **Advanced LinCMOS™ Technology**
- **Self-Calibration Eliminates Expensive Trimming at Factory and Offset Adjustment in the Field**
- **12-Bit Plus Sign Resolution**
- **12-Bit Linearity**
- **12-μs Conversion Period at $f_{clock} = 2$ MHz†**
- **Compatible With All Microprocessors**
- **Single 5-V and ± 5-V Supply Operation**
- **True Differential Analog Voltage Inputs With $-V_{ref}$ to $V_{ref}$ Differential Input Range**
- **For Single 5-V Supply, Input Common-Mode Voltage Range is 0 V to 5 V**
- **For ± 5-V Supplies, Input Common-Mode Voltage Range is – 5 V to 5 V**
- **Unipolar or Bipolar Operation**
- **2s-Complement Output**
- **Low-Power . . . 85 mW Maximum**

**J OR N PACKAGE**
**(TOP VIEW)**



## description

The TLC1225 converter is manufactured with Texas Instruments highly efficient Advanced LinCMOS™ technology. The TLC1225 CMOS analog-to-digital converter can be operated with a single 5-V supply or with ± 5-V supplies. The differential input range is $-V_{ref}$ to $V_{ref}$ in both supply configurations. The common-mode input range is ANLG $V_{CC-}$ to ANLG $V_{CC+}$. For single 5-V supply operation, grounding IN– corresponds to standard unipolar conversion. For ±5-V supply operation, grounding IN– corresponds to standard bipolar conversion. Conversion is performed via the successive-approximation method. The TLC1225 outputs the converted data in a parallel word and interfaces directly to a 16-bit data bus. Negative numbers are given in the twos-complement data format. All digital signals are fully TTL and CMOS compatible.

This converter uses a self-calibration technique by which seven of the internal capacitors in the capacitive array of the A/D conversion circuitry can be automatically calibrated. The internal capacitors are calibrated during a nonconversion capacitor-calibrate cycle in which all seven of the internal capacitors are calibrated at the same time. A conversion period requires only 24 clock cycles. Self-calibration requires 300 clock cycles. The calibration or conversion cycle can be initiated at any time by issuing the proper command word to the data bus. The self-calibrating technique eliminates the need for expensive trimming of thin-film resistors at the factory and provides excellent performance at low cost.

The TLC1225I is characterized for operation from – 40°C to 85°C.

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† The conversion period is the reciprocal of the conversion rate and includes the access, sample, setup, and A/D conversion times.
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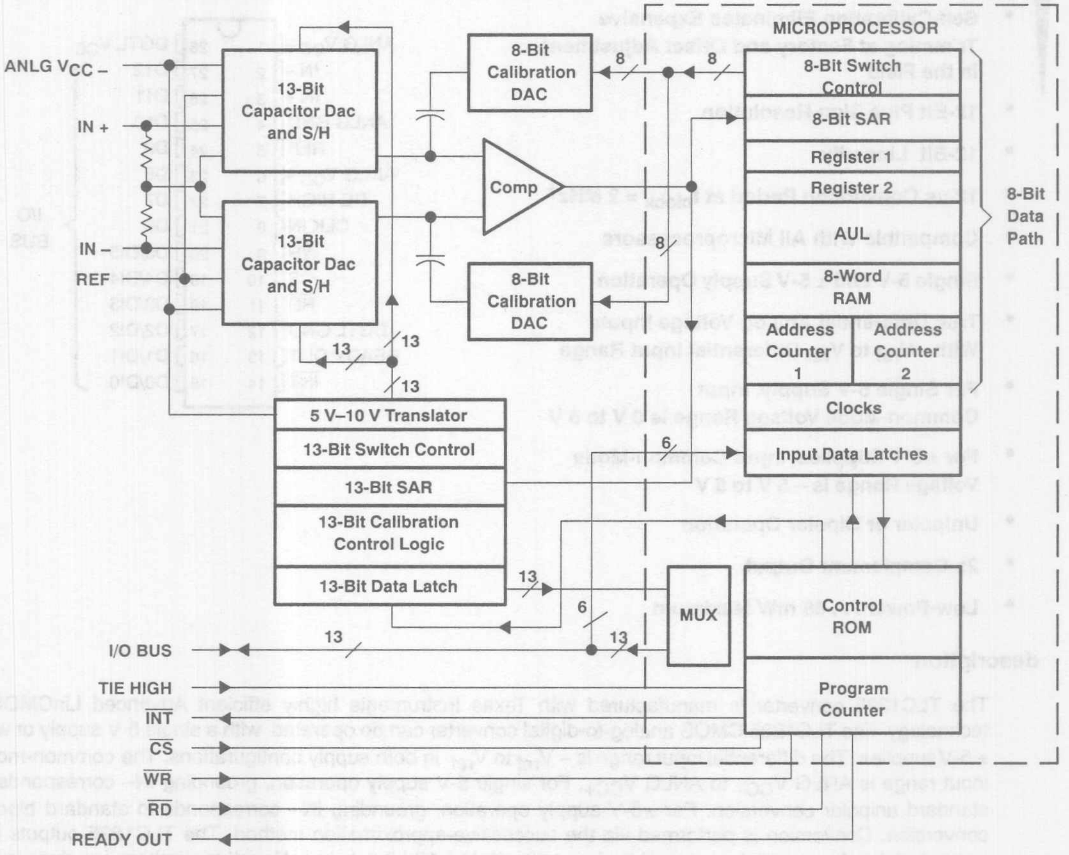
## functional block diagram



## operation description

### calibration of comparator offset

The following actions are performed to calibrate the comparator offset:

1) The IN+ and IN – inputs are internally shorted together so that the converter input is zero. A course comparator offset calibration is performed by storing the offset voltages of the interconnecting comparator stages on the coupling capacitors that connect these stages. Refer to Figure 1. The storage of offset voltages is accomplished by closing all switches and then opening switches A and A', then switches B and B', and then C and C'. This process continues until all interconnecting stages of the comparator are calibrated. After this action, some of the comparator offset still remains uncalibrated.

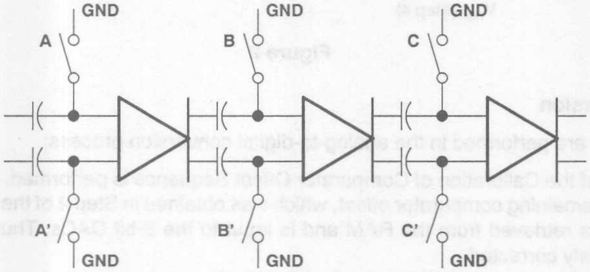


Figure 1

2) An A/D conversion is done on the remaining offset with the 8-bit calibration DACs and 8-bit SAR, and the result is stored in the RAM.

### calibration of the ADC's capacitive capacitor array

The following actions are performed to calibrate capacitors in the 13-bit DACs that comprise the ADC's capacitive array:

1) The IN + and IN – inputs are internally disconnected from the 13-bit DACs.
2) The most significant bit (MSB) capacitor is tied to REF, while the rest of the array capacitors are tied to GND. The A/D conversion result for the remaining comparator offset, obtained in Step 2 above, is retrieved from the RAM and is input to the 8-bit DACs.
3) Step 1 of the Calibration of Comparator Offset sequence is performed. The 8-bit DAC input is returned to zero and the remaining comparator offset is then subtracted. Thus the comparator offset is completely corrected.
4) Now the MSB capacitor is tied to GND, while the rest of the array capacitors, $C_X$, are tied to REF. An MSB capacitor voltage error (see Figure 2) on the comparator output will occur if the MSB capacitor does not equal the sum of the other capacitors in the capacitive array. This error voltage is converted to an 8-bit word from which a capacitor error is computed and stored in the RAM.
5) The capacitor voltage error for the next most significant capacitor is calibrated by keeping the MSB capacitor grounded and then performing the above Steps 1-4 while using the next most significant capacitor in lieu of the MSB capacitor. The seven most significant capacitors are calibrated in this manner.

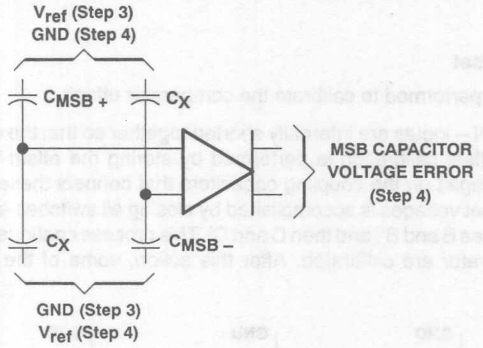


Figure 2

### analog-to-digital conversion

The following steps are performed in the analog-to-digital conversion process:

1) Step 1 of the Calibration of Comparator Offset Sequence is performed. The A/D conversion result for the remaining comparator offset, which was obtained in Step 2 of the Calibration of Comparator Offset, is retrieved from the RAM and is input to the 8-bit DACs. Thus the comparator offset is completely corrected.
2) IN +and IN – are sampled into the 13-bit capacitive arrays.
3) The 13-bit analog-to-digital conversion is performed. As the successive-approximation conversion proceeds successively through the seven most significant capacitors, the error for each of these capacitors is recovered from the RAM and accumulated in a register. This register controls the 8-bit DACs so the total accumulated error for these capacitors is subtracted out during the conversion process.

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|---|
| Supply voltage (ANLG $V_{CC+}$ and DGTL.$V_{CC}$) (see Note 1) | 15 V |
| Supply voltage, ANLG $V_{CC-}$ | – 15 V |
| Differential supply voltage, ANLG $V_{CC+}$ – ANLG $V_{CC-}$ | 20 V |
| Clock input voltage range | – 0.3 V to $V_{CC}$ + 0.3 V |
| Control input voltage range | – 0.3 V to $V_{CC}$ + 0.3 V |
| Analog input (IN +, IN –) voltage range, $V_{I+}$ and $V_{I-}$ | ANLG $V_{CC-}$ – 0.3 V to ANLG VCC + + 0.3 V |
| Reference voltage range, $V_{ref}$ | – 0.3 V to ANLG $V_{CC+}$ + 0.3 V |
| Pin 7 voltage range | – 0.3 V to ANLG $V_{CC+}$ + 0.3 V |
| Output voltage range | – 0.3 V to DGTL $V_{CC}$ + 0.3 V |
| Input current (per pin) | ± 5 mA |
| Input current (per package) | ± 20 mA |
| Operating free-air temperature range, $T_A$ | – 40°C to 85°C |
| Storage temperature range | – 65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from the case for 60 seconds: J package | 300°C |
| Lead temperature 1,6 mm (1/16 inch) from the case for 10 seconds: N package | 260°C |

NOTE 1: All analog voltages are referred to ANLG GND and all digital voltages are referred to DGTL GND.

## recommended operating conditions

| | | MIN | MAX | UNIT |
|---|---|---|---|---|
| Supply voltage | ANLG $V_{CC+}$ | 4.5 | 5.5 | V |
| | ANLG $V_{CC-}$ | $-5.5$ | ANLG GND | |
| | DGTL $V_{CC}$ | 4.5 | 5.5 | |
| High-level input voltage, $V_{IH}$ ($V_{CC}$ = 4.75 V to 5.25 V) | All digital inputs except CLK IN | 2 | | V |
| | CLK IN | 3.5 | | |
| Low-level input voltage, $V_{IL}$ ($V_{CC}$ = 4.75 V to 5.25 V) | All digital inputs except CLK IN | | 0.8 | V |
| | CLK IN | | 1.4 | |
| Analog input voltage, $V_{I+}$, $V_{I-}$ | | ANLG $V_{CC-}$ − 0.05 | ANLG $V_{CC+}$ 0.05 | V |
| Pin 7 (TIE HIGH) | $V_{CC}$ = 5 V | 2 | | V |
| Clock input frequency, $f_{clock}$ | $V_{CC}$ = 5 V | 0.3 | 2 | MHz |
| Clock duty cycle | $V_{CC}$ = 5 V | 40% | 60% | |
| Pulse duration, $\overline{CS}$ and $\overline{WR}$ low, $t_w$ | $V_{CC}$ = 5 V | 15 | | ns |
| Setup time before $\overline{WR}$↑ or $\overline{CS}$↑, $t_{su}$ | $V_{CC}$ = 5 V | 60 | | ns |
| Hold time after $\overline{WR}$↑ or $\overline{CS}$↑, $t_h$ | $V_{CC}$ = 5 V | 50 | | ns |
| Operating free-air temperature, $T_A$ | | − 40 | 85 | °C |

## electrical characteristics over recommended operating free-air temperature range, ANLG $V_{CC+}$ = DGTL $V_{CC}$ = $V_{ref}$ = 5 V, ANLG $V_{CC-}$ = − 5 V or ANLG GND (unless otherwise noted) (see Note 2)

| PARAMETER | | TEST CONDITIONS | | MIN | MAX | UNIT |
|---|---|---|---|---|---|---|
| $V_{OH}$ | High-level output voltage | DGTL $V_{CC}$ = 4.75 V | $I_O$ = − 1.8 mA | 2.4 | | V |
| | | | $I_O$ = − 50 µA | 4.5 | | |
| $V_{OL}$ | Low-level output voltage | DGTL $V_{CC}$ = 4.75 V, | $I_O$ = 3.2 mA | | 0.4 | V |
| $r_{ref}$ | Input resistance, REF terminal | | | 1 | 10 | MΩ |
| $I_{IH}$ | High-level input current | $V_I$ = 5 V | | | 1 | µA |
| $I_{IL}$ | Low-level input current | $V_I$ = 0 | | | − 1 | µA |
| $I_{OZ}$ | High-impedance-state output leakage current | $V_O$ = 0 | | | − 3 | µA |
| | | $V_O$ = 5 V | | | 3 | |
| $I_O$ | Output current | $V_O$ = 0 | | − 6 | | mA |
| | | $V_O$ = 5 V | | 8 | | |
| DGTL $I_{CC}$ | Supply current from DGTL $V_{CC}$ | $f_{clock}$ = 2 MHz, | $\overline{CS}$ high | | 6 | mA |
| ANLG $I_{CC+}$ | Supply current from ANLG $V_{CC+}$ | $f_{clock}$ = 2 MHz, | $\overline{CS}$ high | | 8 | mA |
| ANLG $I_{CC-}$ | Supply current from ANLG $V_{CC-}$ | $f_{clock}$ = 2 MHz, | $\overline{CS}$ high | | − 3 | mA |

NOTE 2: The input voltage range is defined as: $V_{I+} = -5.05$ V to 5.05 V, $V_{I-} = -5.05$ V to 5.05 V, and $|V_{I+} - V_{I-}| \le 5.05$ V when ANLG $V_{CC-} = -5$ V. The input voltage range is defined as: $V_{I+} = -0.05$ V to 5.05 V, $V_{I-} = -0.05$ V to 5.05 V, and $|V_{I+} - V_{I-}| \le 5.05$ V when ANLG $V_{CC-}$ = ANLG GND.

## electrical characteristics over recommended operating free-air temperature range, ANLG $V_{CC+}$ = DGTL $V_{CC}$ = $V_{ref}$ = 5 V, ANLG $V_{CC-}$ = – 5 V or ANLG GND, $f_{clock}$ = 2 MHz (unless otherwise noted) (see Note 2)

| PARAMETER | | | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $E_L$ | Integral linearity error | | | | | ± 0.012% | FSR‡ |
| $E_D$ | Differential linearity | | – 5 V < (IN + – IN –) < 5 V,<br>$V_{CC+}$ = 5 V, $V_{CC-}$ = – 5 V | > – 1 | | 1 | LSB§ |
| | | | 0 < (IN + – IN –) < 5.05 V,<br>$V_{CC+}$ = 5 V, $V_{CC-}$ = 0 | > – 1 | | 1 | |
| | Zero error | | | | | ± 1.5 | LSB |
| | Unadjusted positive and negative full-scale error | | | | | ± 2 | LSB |
| | Temperature coefficient of gain | | | | 15 | | ppm/°C |
| | Temperature coefficient of offset point | | | | 1.5 | | ppm/°C |
| $k_{SVS}$ | Supply voltage sensitivity | Zero error | ANLG $V_{CC+}$ = 5 V ± 5%,<br>ANLG $V_{CC-}$ = – 5 V ±5%,<br>DGTL $V_{CC}$ = 5 V ± 5% | | ± 0.75 | | LSB |
| | | Positive and negative full-scale error | | | ± 0.75 | | |
| | | Linearity error | | | ± 0.25 | | |
| CMRR | Common-mode rejection ratio | | IN – = IN + = – 5 V to 5 V | | 65 | | dB |
| | Common-mode rejection (maximum code change from code 0000000000000) | | IN – = IN + = – 5 V to 5 V | | 2 | | LSB |
| $t_{period}$ | Conversion period (1/$f_{clk}$) (see Notes 3 and 4) | | | | | 24 | clock cycles |
| $t_a$ | Access time (delay from falling edge of $\overline{CS} \cdot \overline{RD}$ to data output) | | $C_L$ = 100 pF | | | 95 | ns |
| $t_{dis}$ | Disable time, output (delay from rising edge of $\overline{RD}$ to high-impedance state) | | $R_L$ = 2 kΩ, $C_L$ = 100 pF | | | 90 | ns |
| $t_{d1(READY)}$ | Control signal edge to READY OUT delay time | | | 100 | | | ns |
| $t_{d2(READY)}$ | Control signal edge to READY OUT delay time | | | | | 100 | ns |
| $t_{d(INT)}$ | $\overline{RD}$ or $\overline{WR}$ to reset of $\overline{INT}$ delay time | | | | | 100 | ns |

† All typical values are at $T_A$ = 25°C.

‡ FSR is Full-Scale Range: 0.012% FSR linearity error is equivalent to 1 LSB = 1.22 mV.

§ No missing codes.

NOTES: 2. The input voltage range is defined as: $V_{I+}$ = – 5.05 V to 5.05 V, $V_{I-}$ = – 5.05 V to 5.05 V, and | $V_{I+}$ – $V_{I-}$ | ≤ 5.05 V when ANLG $V_{CC-}$ = – 5 V. The input voltage range is defined as: $V_{I+}$ = – 0.05 V to 5.05 V, $V_{I-}$ = – 0.05 V to 5.05 V, and | $V_{I+}$ – $V_{I-}$ | ≤ 5.05 V when ANLG $V_{CC-}$ = ANLG GND.

3. If $\overline{INT}$ and $\overline{RD}$ go low within the same $f_{clock}$ period, $\overline{INT}$ will not be reset until $\overline{WR}$ is brought low. If $\overline{INT}$ and $\overline{RD}$ do not go low within the same $f_{clock}$ period, $\overline{INT}$ will be reset.

4. The conversion period is the reciprocal of the conversion rate and includes the access, sample, setup, and A/D conversion times.

## PARAMETER MEASUREMENT INFORMATION

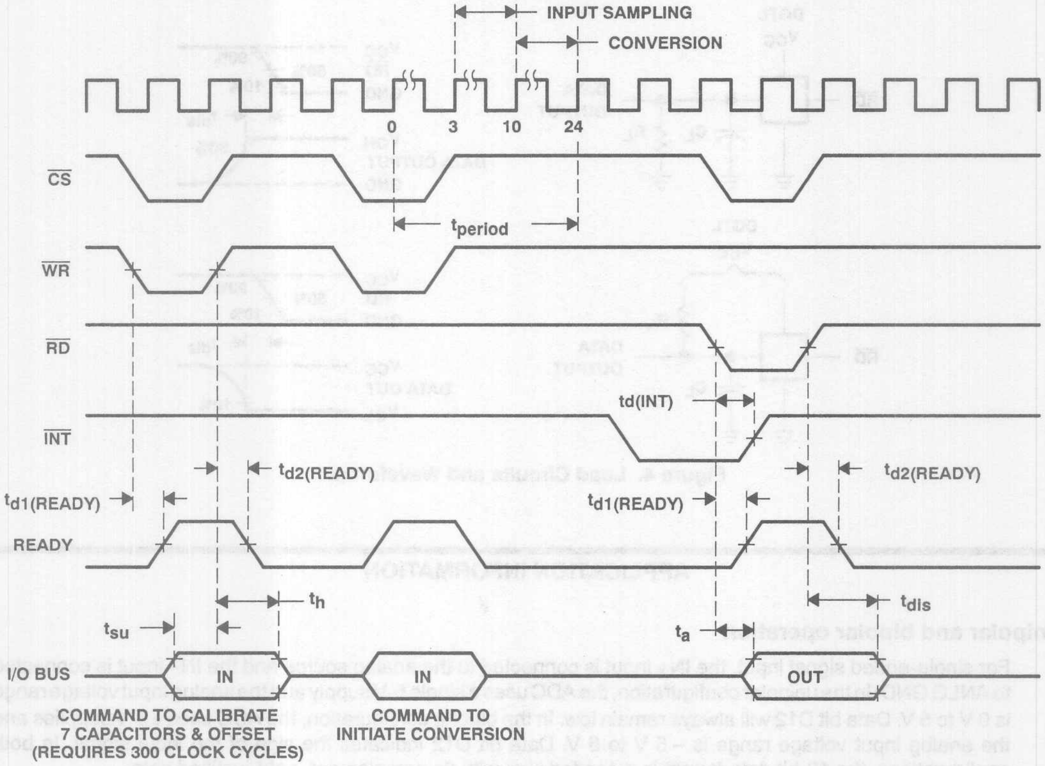


Figure 3. Timing Diagram

## PARAMETER MEASUREMENT INFORMATION

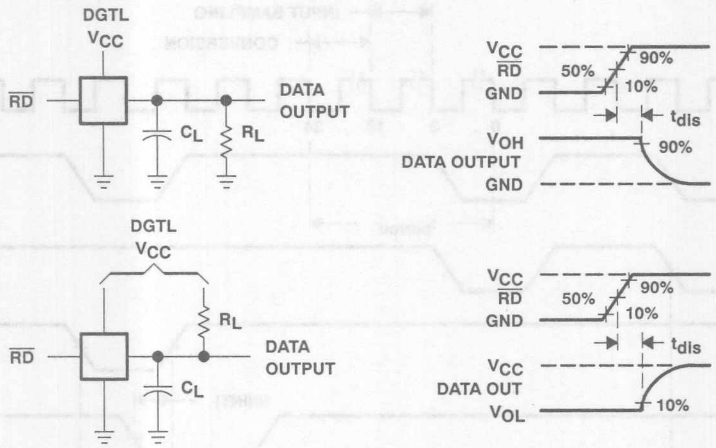


Figure 4. Load Circuits and Waveforms

## APPLICATION INFORMATION

### unipolar and bipolar operation

For single-ended signal input, the IN+ input is connected to the analog source and the IN– input is connected to ANLG GND. In the unipolar configuration, the ADC uses a single 5-V supply and the analog input voltage range is 0 V to 5 V. Data bit D12 will always remain low. In the bipolar configuration, the ADC uses ±5-V supplies and the analog input voltage range is – 5 V to 5 V. Data bit D12 indicates the sign of the input signal. In both configurations, the 13-bit data format is extended sign with 2s-complement, right-justified data.

### power-up sequence

Calibration is not automatic on power-up. Calibration is initiated by writing control words to the six least significant bits of the data bus. $V_{ref}$ must have fully settled before calibration is initiated. If addressed or initiated, conversion can begin after the first clock cycle. However, full A/D conversion accuracy is not established until after internal capacitor calibration.

### conversion period start sequence

The writing of the conversion command word to the six least significant bits of the data bus, when either $\overline{\text{CS}}$ or $\overline{\text{WR}}$ goes high, initiates the conversion sequence.

### analog sampling sequence

Sampling of the input signal occurs during clock cycles 3 through 10 of the conversion sequence.

### completed A/D conversion

When $\overline{\text{INT}}$ goes low, conversion is complete and the A/D result can be read. A new conversion period can begin immediately. The A/D conversion is complete at the end of clock cycle 24 of the conversion period.

### aborting a conversion period in process and beginning a new conversion

If a conversion period is initiated while a conversion sequence is in process, the ongoing conversion will be aborted and a new conversion period will begin.

### reading the conversion result

When both $\overline{CS}$ and $\overline{RD}$ go low, all 13 bits of conversion data are output to the I/O bus. The format of the output is extended sign with 2s-complement, right-justified data. The sign bit D12 is low if $V_{I+} - V_{I-}$ is positive and high if $V_{I+} - V_{I-}$ is negative.

### general

#### reset $\overline{INT}$

When reading the conversion data, the falling edge of the first low-going combination of $\overline{CS}$ and $\overline{RD}$ will reset $\overline{INT}$. The falling edge of the low-going combination of $\overline{CS}$ and $\overline{WR}$ will also reset $\overline{INT}$.

#### ready out

For high-speed microprocessors, READY OUT allows the TLC1225 to insert a wait state in the microprocessor's read or write cycle.

#### reference voltage ($V_{ref}$)

This voltage defines the range for $|V_{I+} - V_{I-}|$. When $|V_{I+} - V_{I-}|$ equals $V_{ref}$, the highest conversion data value results. When $|V_{I+} - V_{I-}|$ equals 0, the conversion data value is zero. Thus, for a given input, the conversion data changes ratiometrically with changes in $V_{ref}$. Calibration should be performed with the same value of $V_{ref}$ as will be used during conversion.

#### TIE HIGH

This pin is a digital input and should be tied high.

### calibration and conversion period considerations

Calibration of the internal capacitors and A/D conversion are two separate actions. Each action is independently initiated. A calibration command should be initiated prior to subsequent conversions. It is not necessary to recalibrate before each conversion. Capacitor calibration is expected to last indefinitely as long as the clock signal and power are not interrupted. However, the offset calibration may drift with temperature changes. The temperature coefficient of the offset point is shown in the electrical characteristics table. Periodic calibration is recommended. Calibration and conversion commands require 300 and 24 clock cycles, respectively.

The calibrate and conversion commands are initiated by writing control words on the six least significant bits of the data bus. These control words are written into the IC when either $\overline{CS}$ or $\overline{WR}$ goes high. The initiation of these commands is illustrated in the Timing Diagram. The bit patterns for the commands are shown in Table 1.

**Table 1. Conversion Commands**

| COMMAND | $\overline{CS}$ + $\overline{WR}$ | I/O BUS D15 | D14 | D13 | D12 | D11 | D10 | REQUIRED NUMBER OF CLOCK CYCLES |
|---|---|---|---|---|---|---|---|---|
| Conversion | ↑ | H | L | X | X | X | L | 24 |
| Calibrate† | ↑ | L | X | L | L | L | L | 300 |

† Calibration is lost when clock is stopped.

## analog inputs

### differential inputs provide common-mode rejection

The differential inputs reduce common-mode noise. Common-mode noise is noise common to both IN + and IN − inputs, such as 60-Hz noise. There is no time interval between the sampling of the IN + and IN − so these inputs are truly differential. Thus no conversion errors result from a time interval between the sampling of the IN + and IN − inputs.

### input bypass capacitors

Input bypass capacitors can be used for noise filtering. However, the charge on these bypass capacitors will be depleted during the input sampling sequence when the internal sampling capacitors are charged. Note that the charging of the bypass capacitors through the differential source resistances must keep pace with the charge depletion of the bypass capacitors during the input sampling sequence. Higher source resistances reduce the amount of charging current for the bypass capacitors. Also, note that fast, successive conversion has the greatest charge depletion effect on the bypass capacitors. Therefore, the above phenomenon becomes more significant as source resistances and the conversion rate (i.e., higher clock frequency and conversion initiation rate) increase.

In addition, if the above phenomenon prevents the bypass capacitors from fully charging between conversions, voltage drops across the source resistances will result due to the ongoing bypass capacitor charging currents. The voltage drops cause a conversion error. Also, the voltage drops increase with higher $|V_{I+} - V_{I-}|$ values, higher source resistances, and lower charge on the bypass capacitors (i.e., faster conversion rate).

For low-source-resistance applications ($R_{source} < 100\ \Omega$), a 0.001-µF bypass capacitor at the inputs prevents pickup due to the series lead inductance of a long wire. A 100-Ω resistor can be placed between the capacitor and the output of an operational amplifier to isolate the capacitor from the operational amplifier.

### input leads

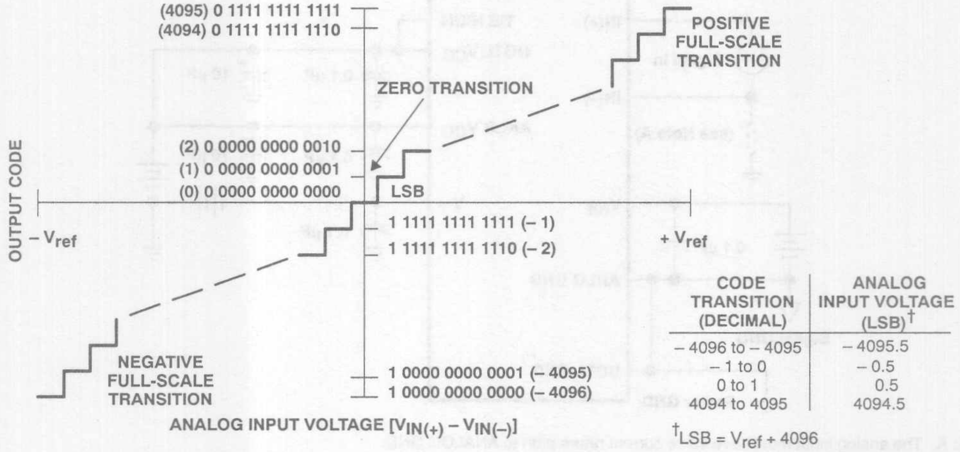
The input leads should be kept as short as possible since the coupling of noise and digital clock signals to the the inputs can cause errors.

### power supply considerations

Noise spikes on the $V_{CC}$ lines can cause conversion error. Low-inductance tantalum capacitors (> 1 µF) with short leads should be used to bypass ANLG $V_{CC}$ and DGTL $V_{CC}$. A separate regulator for the TLC1225 and other analog circuitry greatly reduces digital noise on the supply line.

A ferrite bead or equivalent inductance can be used between the analog and digital ground planes if the digital ground noise is excessive.

## APPLICATION INFORMATION

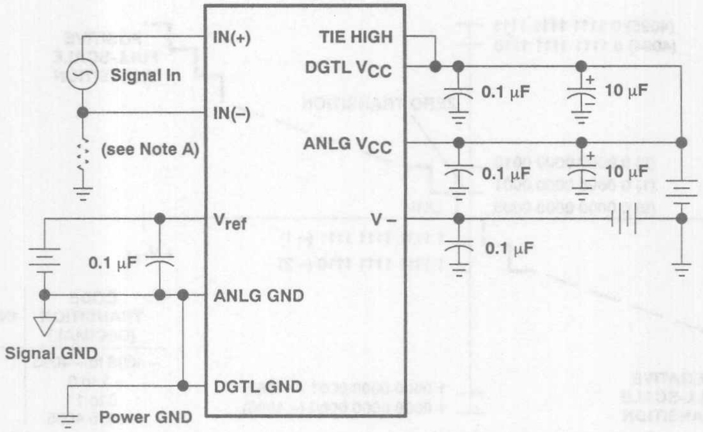


| CODE TRANSITION (DECIMAL) | ANALOG INPUT VOLTAGE (LSB)[†] |
|---|---|
| – 4096 to – 4095 | – 4095.5 |
| – 1 to 0 | – 0.5 |
| 0 to 1 | 0.5 |
| 4094 to 4095 | 4094.5 |

[†] LSB = $V_{ref}$ ÷ 4096

Figure 5. Transfer Characteristic

## APPLICATION INFORMATION



NOTES: A. The analog input must have some current return path to ANALOG GND.
B. Bypass capacitor leads must be as short as possible.
C. For high-accuracy applications, use a larger capacitor to reduce reference noise.

Figure 6. Analog Considerations

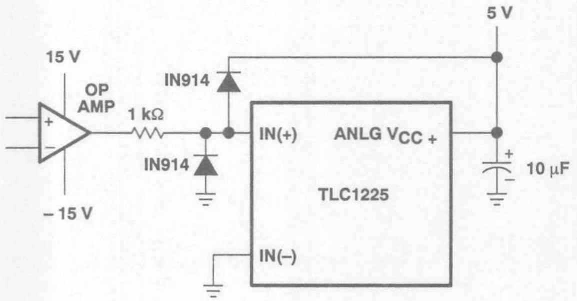
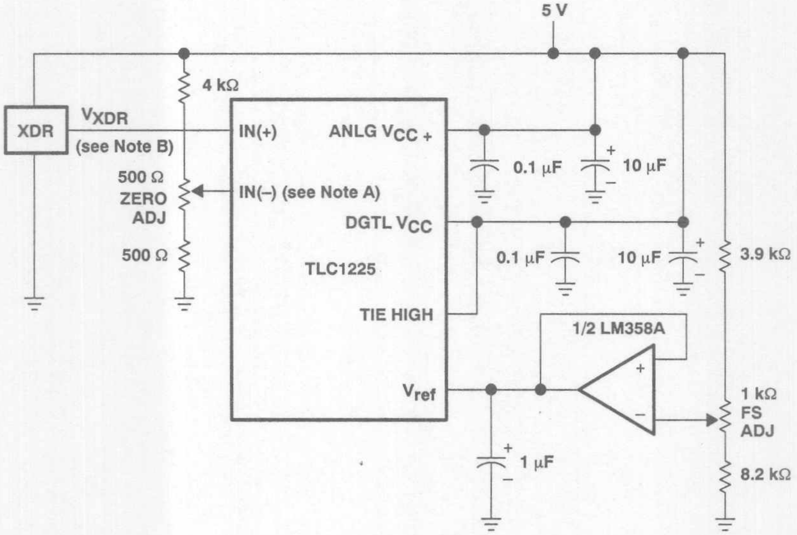


Figure 7. Input Protection

## APPLICATION INFORMATION



NOTES: A. $V_I = 0.15 \times$ ANLG $V_{CC+}$.
B. 15% of ANALOG $V_{CC} \le V_{XDR} \le$ 85% of ANALOG $V_{CC}$.

Figure 8. Operating with Ratiometric Transducers

# TLC2202, TLC2202A, TLC2202B
# Advanced LinCMOS™ LOW-NOISE PRECISION DUAL OPERATIONAL AMPLIFIERS

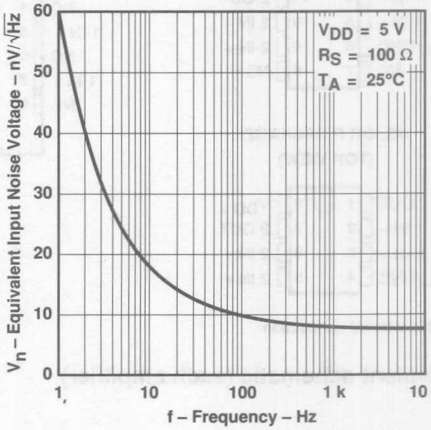
D3497, MAY 1990

- **TLC2202B Is 100% Tested for Noise:**
  **25 nV/$\sqrt{\text{Hz}}$ Max at f = 10 Hz**
  **12 nV/$\sqrt{\text{Hz}}$ Max at f = 1 kHz**
- **Low Input Offset Voltage . . . 500 µV Max**
- **Excellent Offset Voltage Stability with Temperature . . . 0.5 µV/°C Typ**
- **Rail-to-Rail Output Swing**
- **Low Input Bias Current . . . 1 pA Typ at $T_A$ = 25°C**
- **Common-Mode Input Voltage Range Includes the Negative Rail**

## description

The TLC2202, TLC2202A, and TLC2202B are precision, low-noise operational amplifiers using Texas Instruments Advanced LinCMOS™ process. These devices combine the noise performance of the lowest-noise JFET amplifiers with the dc precision available previously only in bipolar amplifiers. The Advanced LinCMOS™ process uses silicon-gate technology to obtain input offset voltage stability with temperature and time that far exceeds that obtainable using metal-gate technology. In addition, this technology makes possible input impedance levels that meet or exceed levels offered by top-gate JFET and expensive dielectric-isolated devices.

The combination of excellent dc and noise performance with a common-mode input voltage range that includes the negative rail makes these devices an ideal choice for high-impedance, low-level signal-conditioning applications in either single-supply or split-supply configurations.


TYPICAL EQUIVALENT INPUT NOISE VOLTAGE vs FREQUENCY

The device inputs and outputs are designed to withstand −100-mA surge currents without sustaining latchup. In addition, internal ESD protection circuits prevent functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2; however, care should be exercised in handling these devices as exposure to ESD may result in degradation of the device parametric performance.

AVAILABLE OPTIONS

| $T_A$ | $V_{IO}$ max AT 25°C | $V_n$ max f = 10 Hz AT 25°C | $V_n$ max f = 1 kHz AT 25°C | PACKAGE | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | SMALL-OUTLINE (D) | CHIP CARRIER (FK) | CERAMIC DIP (JG) | METAL CAN (L) | PLASTIC DIP (P) |
| 0°C | 500 µV | 25 nV/$\sqrt{\text{Hz}}$ | 12 nV/$\sqrt{\text{Hz}}$ | TLC2202BCD | —— | —— | TLC2202BCL | TLC2202BCP |
| to | 500 µV | 35 nV/$\sqrt{\text{Hz}}$ | 15 nV/$\sqrt{\text{Hz}}$ | TLC2202ACD | —— | —— | TLC2202ACL | TLC2202ACP |
| 70°C | 1 mV | —— | —— | TLC2202CD | —— | —— | TLC2202CL | TLC2202CP |
| − 40°C | 500 µV | 25 nV/$\sqrt{\text{Hz}}$ | 12 nV/$\sqrt{\text{Hz}}$ | TLC2202BID | —— | —— | TLC2202BIL | TLC2202BIP |
| to | 500 µV | 35 nV/$\sqrt{\text{Hz}}$ | 15 nV/$\sqrt{\text{Hz}}$ | TLC2202AID | —— | —— | TLC2202AIL | TLC2202AIP |
| 85°C | 1 mV | —— | —— | TLC2202ID | —— | —— | TLC2202IL | TLC2202IP |
| − 55°C | 500 µV | 25 nV/$\sqrt{\text{Hz}}$ | 12 nV/$\sqrt{\text{Hz}}$ | TLC2202BMD | TLC2202BMFK | TLC2202BMJG | TLC2202BML | TLC2202BMP |
| to | 500 µV | 35 nV/$\sqrt{\text{Hz}}$ | 15 nV/$\sqrt{\text{Hz}}$ | TLC2202AMD | TLC2202AMFK | TLC2202AMJG | TLC2202AML | TLC2202AMP |
| 125°C | 1 mV | —— | —— | TLC2202MD | TLC2202MFK | TLC2202MJG | TLC2202ML | TLC2202MP |

D packages are available taped-and-reeled. Add "R" suffix to device type (e.g., TLC2202BCDR).

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**PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.**

TEXAS INSTRUMENTS

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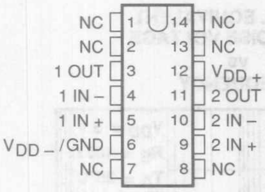
**On products compliant to MIL-STD-883, Class B, all parameters are tested unless otherwise noted. On all other products, production processing does not necessarily include testing of all parameters.**

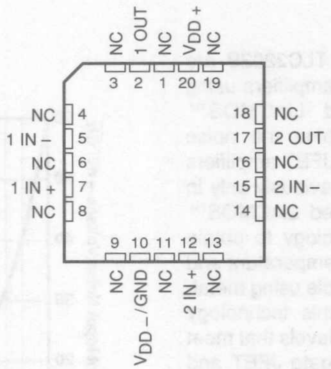
## description (continued)

The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from −40°C to 85°C. The M-suffix devices are characterized for operation over the full military temperature range of −55°C to 125°C.

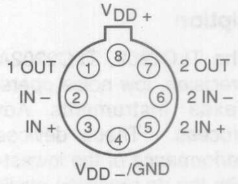
D PACKAGE
(TOP VIEW)



FK PACKAGE
(TOP VIEW)

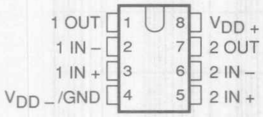


L PACKAGE
(TOP VIEW)



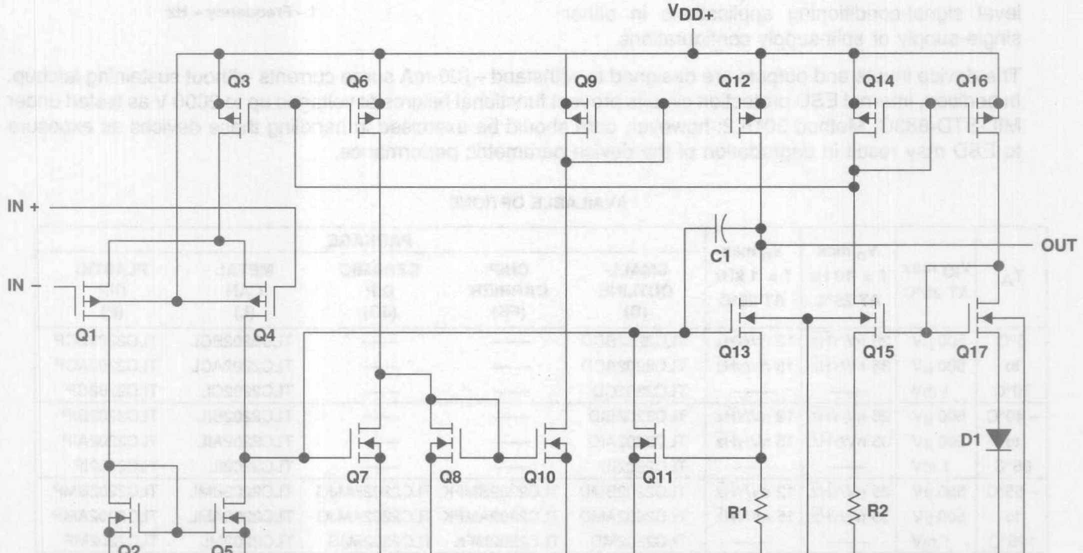
Pin 4 of the L package is in electrical contact with the case.

JG, OR P PACKAGE
(TOP VIEW)



NC – No internal connection

## equivalent schematic (each amplifier)



## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|---|
| Supply voltage, $V_{DD+}$ (see Note 1) | 8 V |
| Supply voltage, $V_{DD-}$ | − 8 V |
| Differential input voltage (see Note 2) | ± 16 V |
| Input voltage range, $V_I$ (any input) | ± 8 V |
| Input current, $I_I$ (each input) | ± 5 mA |
| Output current, $I_O$ (each output) | ± 50 mA |
| Duration of short-circuit current at (or below) 25°C (see Note 3) | unlimited |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range, $T_A$: C-suffix | 0°C to 70°C |
| I-suffix | − 40°C to 85°C |
| M-suffix | − 55°C to 125°C |
| Storage temperature range | − 65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG or L package | 300°C |

NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between $V_{DD+}$ and $V_{DD-}$.
2. Differential voltages are at the noninverting input with respect to the inverting input.
3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \le 25°C$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25°C$ | $T_A = 70°C$ POWER RATING | $T_A = 85°C$ POWER RATING | $T_A = 125°C$ POWER RATING |
|---|---|---|---|---|---|
| D | 950 mW | 7.6 mW/°C | 608 mW | 494 mW | 190 mW |
| FK | 1375 mW | 11.0 mW/°C | 880 mW | 715 mW | 275 mW |
| JG | 1050 mW | 8.4 mW/°C | 672 mW | 546 mW | 210 mW |
| L | 650 mW | 5.2 mW/°C | 416 mW | 338 mW | 130 mW |
| P | 1000 mW | 8.0 mW/°C | 640 mW | 520 mW | 200 mW |

## recommended operating conditions

| | C-SUFFIX | | I-SUFFIX | | M-SUFFIX | | UNIT |
|---|---|---|---|---|---|---|---|
| | MIN | MAX | MIN | MAX | MIN | MAX | |
| Supply voltage, $V_{DD}$ | ± 2.3 | ± 8 | ± 2.3 | ± 8 | ± 2.3 | ± 8 | V |
| Common-mode input voltage, $V_{IC}$ | $V_{DD-}$ | $V_{DD+} - 2.3$ | $V_{DD-}$ | $V_{DD+} - 2.3$ | $V_{DD-}$ | $V_{DD+} - 2.3$ | V |
| Operating free-air temperature, $T_A$ | 0 | 70 | − 40 | 85 | − 55 | 125 | °C |

## electrical characteristics at specified free-air temperature, $V_{DD\pm} = \pm 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLC2202C | | | UNIT |
|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 100 | 1000 | µV |
| | | | Full range | | | 1150 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | 0°C to 70°C | | 0.5 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.001 | 0.005 | µV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 0.5 | | pA |
| | | | Full range | | | 100 | |
| $I_{IB}$ | Input bias current | | 25°C | | 1 | | pA |
| | | | Full range | | | 100 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | Full range | −5 to 2.7 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $R_L = 10\ k\Omega$ | 25°C | 4.7 | 4.8 | | V |
| | | | Full range | 4.7 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | 25°C | −4.7 | −4.9 | | V |
| | | | Full range | −4.7 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = \pm 4$ V, $R_L = 500\ k\Omega$ | 25°C | 400 | 560 | | V/mV |
| | | | Full range | 300 | | | |
| | | $V_O = \pm 4$ V, $R_L = 10\ k\Omega$ | 25°C | 90 | 100 | | |
| | | | Full range | 70 | | | |
| CMRR | Common-mode rejection ratio | $V_O = 0$, $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 25°C | 80 | 115 | | dB |
| | | | Full range | 80 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{DD\pm} / \Delta V_{IO}$) | $V_{DD\pm} = \pm 2.3$ V to ±8 V | 25°C | 80 | 110 | | dB |
| | | | Full range | 80 | | | |
| $I_{DD}$ | Supply current | $V_O = 0$, No load | 25°C | | 1.8 | 2.5 | mA |
| | | | Full range | | | 2.5 | |

## operating characteristics at specified free-air temperature, $V_{DD\pm} = \pm 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLC2202C | | | UNIT |
|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O = \pm 2.3$ V, $R_L = 10\ k\Omega$, $C_L = 100$ pF | 25°C | 2 | 2.7 | | V/µs |
| | | | Full range | 1.5 | | | |
| $V_n$ | Equivalent input noise voltage | f = 10 Hz | 25°C | | 18 | | nV/√Hz |
| | | f = 1 kHz | 25°C | | 8 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.5 | | µV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.7 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.6 | | fA/√Hz |
| | Gain-bandwidth product | f = 10 kHz, $R_L = 10\ k\Omega$, $C_L = 100$ pF | 25°C | | 1.9 | | MHz |
| $\phi_m$ | Phase margin at unity gain | $R_L = 10\ k\Omega$, $C_L = 100$ pF | 25°C | | 48° | | |

†Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## electrical characteristics at specified free-air temperature, $V_{DD\pm} = \pm 5$ V (unless otherwise noted)

| | PARAMETER | TEST CONDITIONS | $T_A$† | TLC2202AC | | | TLC2202BC | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 80 | 500 | | 80 | 500 | µV |
| | | | Full range | | | 650 | | | 650 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | 0°C to 70°C | | 0.5 | | | 0.5 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.001 | 0.005 | | 0.001 | 0.005 | µV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 0.5 | | | 0.5 | | pA |
| | | | Full range | | | 100 | | | 100 | |
| $I_{IB}$ | Input bias current | | 25°C | | 1 | | | 1 | | pA |
| | | | Full range | | | 100 | | | 100 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | Full range | −5<br>to<br>2.7 | | | −5<br>to<br>2.7 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $R_L = 10\ k\Omega$ | 25°C | 4.7 | 4.8 | | 4.7 | 4.8 | | V |
| | | | Full range | 4.7 | | | 4.7 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | 25°C | −4.7 | −4.9 | | −4.7 | −4.9 | | V |
| | | | Full range | −4.7 | | | −4.7 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = \pm 4$ V,<br>$R_L = 500\ k\Omega$ | 25°C | 400 | 560 | | 400 | 560 | | V/mV |
| | | | Full range | 300 | | | 300 | | | |
| | | $V_O = \pm 4$ V,<br>$R_L = 10\ k\Omega$ | 25°C | 90 | 100 | | 90 | 100 | | |
| | | | Full range | 70 | | | 70 | | | |
| CMRR | Common-mode rejection ratio | $V_O = 0$, $V_{IC} = V_{ICR}$ min,<br>$R_S = 50\ \Omega$ | 25°C | 80 | 115 | | 80 | 115 | | dB |
| | | | Full range | 80 | | | 80 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{DD\pm} / \Delta V_{IO}$) | $V_{DD\pm} = \pm 2.3$ V to $\pm 8$ V | 25°C | 80 | 110 | | 80 | 110 | | dB |
| | | | Full range | 80 | | | 80 | | | |
| $I_{DD}$ | Supply current | $V_O = 0$, No load | 25°C | | 1.8 | 2.5 | | 1.8 | 2.5 | mA |
| | | | Full range | | | 2.5 | | | 2.5 | |

## operating characteristics at specified free-air temperature, $V_{DD\pm} = \pm 5$ V (unless otherwise noted)

| | PARAMETER | TEST CONDITIONS | $T_A$† | TLC2202AC | | | TLC2202BC | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O = \pm 2.3$ V,<br>$R_L = 10\ k\Omega$,<br>$C_L = 100$ pF | 25°C | 2 | 2.7 | | 2 | 2.7 | | V/µs |
| | | | Full range | 1.5 | | | 1.5 | | | |
| $V_n$ | Equivalent input noise voltage (see Note 5) | f = 10 Hz | 25°C | | 18 | 35 | | 18 | 25 | nV/√Hz |
| | | f = 1 kHz | 25°C | | 8 | 15 | | 8 | 12 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.5 | | | 0.5 | | µV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.7 | | | 0.7 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.6 | | | 0.6 | | fA/√Hz |
| | Gain-bandwidth product | f = 10 kHz,<br>$R_L = 10\ k\Omega$,<br>$C_L = 100$ pF | 25°C | | 1.9 | | | 1.9 | | MHz |
| $\phi_m$ | Phase margin at unity gain | $R_L = 10\ k\Omega$,<br>$C_L = 100$ pF | 25°C | | 48° | | | 48° | | |

†Full range is 0°C to 70°C.

NOTES: 4. Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

5. This parameter is tested on a sample basis for the TLC2202A and on all devices for the TLC2202B. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

## electrical characteristics at specified free-air temperature, $V_{DD}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLC2202C | | | UNIT |
|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC}$ = 0, $R_S$ = 50 Ω | 25°C | | 100 | 1000 | μV |
| | | | Full range | | | 1150 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | 0°C to 70°C | | 0.5 | | μV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.001 | 0.005 | μV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 0.5 | | pA |
| | | | Full range | | | 100 | |
| $I_{IB}$ | Input bias current | | 25°C | | 1 | | pA |
| | | | Full range | | | 100 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S$ = 50 Ω | Full range | 0 to 2.7 | | | V |
| $V_{OH}$ | Maximum high-level output voltage | $R_L$ = 10 kΩ | 25°C | 4.7 | 4.8 | | V |
| | | | Full range | 4.7 | | | |
| $V_{OL}$ | Maximum low-level output voltage | $I_O$ = 0 | 25°C | | 0 | 50 | mV |
| | | | Full range | | | 50 | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O$ = 1 V to 4 V, $R_L$ = 500 kΩ | 25°C | 150 | 315 | | V/mV |
| | | | Full range | 100 | | | |
| | | $V_O$ = 1 V to 4 V, $R_L$ = 10 kΩ | 25°C | 25 | 55 | | |
| | | | Full range | 15 | | | |
| CMRR | Common-mode rejection ratio | $V_O$ = 0, $V_{IC}$ = $V_{ICR}$ min, $R_S$ = 50 Ω | 25°C | 75 | 110 | | dB |
| | | | Full range | 75 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{DD} / \Delta V_{IO}$) | $V_{DD}$ = 4.6 V to 16 V | 25°C | 80 | 110 | | dB |
| | | | Full range | 80 | | | |
| $I_{DD}$ | Supply current | $V_O$ = 2.5 V, No load | 25°C | | 1.7 | 2.4 | mA |
| | | | Full range | | | 2.4 | |

## operating characteristics at specified free-air temperature, $V_{DD}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLC2202C | | | UNIT |
|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O$ = 0.5 V to 2.5 V, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | 1.8 | 2.5 | | V/μs |
| | | | Full range | 1.3 | | | |
| $V_n$ | Equivalent input noise voltage | f = 10 Hz | 25°C | | 18 | | nV/√Hz |
| | | f = 1 kHz | 25°C | | 8 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.5 | | μV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.7 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.6 | | fA/√Hz |
| | Gain-bandwidth product | f = 10 kHz, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 1.9 | | MHz |
| $\phi_m$ | Phase margin at unity gain | $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 47° | | |

†Full range is 0°C to 70°C

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A$ = 150°C extrapolated to $T_A$ = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## electrical characteristics at specified free-air temperature, $V_{DD}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLC2202AC | | | TLC2202BC | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC}$ = 0, $R_S$ = 50 Ω | 25°C | | 80 | 500 | | 80 | 500 | μV |
| | | | Full range | | | 650 | | | 650 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | 0°C to 70°C | | 0.5 | | | 0.5 | | μV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.001 | 0.005 | | 0.001 | 0.005 | μV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 0.5 | | | 0.5 | | pA |
| | | | Full range | | | 100 | | | 100 | |
| $I_{IB}$ | Input bias current | | 25°C | | 1 | | | 1 | | pA |
| | | | Full range | | | 100 | | | 100 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S$ = 50 Ω | Full range | 0 to 2.7 | | | 0 to 2.7 | | | V |
| $V_{OH}$ | Maximum high-level output voltage | $R_L$ = 10 kΩ | 25°C | 4.7 | 4.8 | | 4.7 | 4.8 | | V |
| | | | Full range | 4.7 | | | 4.7 | | | |
| $V_{OL}$ | Maximum low-level output voltage | $I_O$ = 0 | 25°C | | 0 | 50 | | 0 | 50 | mV |
| | | | Full range | | | 50 | | | 50 | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O$ = 1 V to 4 V, $R_L$ = 500 kΩ | 25°C | 150 | 315 | | 150 | 315 | | V/mV |
| | | | Full range | 100 | | | 100 | | | |
| | | $V_O$ = 1 V to 4 V, $R_L$ = 10 kΩ | 25°C | 25 | 55 | | 25 | 55 | | |
| | | | Full range | 15 | | | 15 | | | |
| CMRR | Common-mode rejection ratio | $V_O$ = 0, $V_{IC}$ = $V_{ICR}$ min, $R_S$ = 50 Ω | 25°C | 75 | 110 | | 75 | 110 | | dB |
| | | | Full range | 75 | | | 75 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{DD} / \Delta V_{IO}$) | $V_{DD}$ = 4.6 V to 16 V | 25°C | 80 | 110 | | 80 | 110 | | dB |
| | | | Full range | 80 | | | 80 | | | |
| $I_{DD}$ | Supply current | $V_O$ = 2.5 V, No load | 25°C | | 1.7 | 2.4 | | 1.7 | 2.4 | mA |
| | | | Full range | | | 2.4 | | | 2.4 | |

## operating characteristics at specified free-air temperature, $V_{DD}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLC2202AC | | | TLC2202BC | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O$ = 0.5 V to 2.5 V, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | 1.8 | 2.5 | | 1.8 | 2.5 | | V/μs |
| | | | Full range | 1.3 | | | 1.3 | | | |
| $V_n$ | Equivalent input noise voltage (see Note 5) | f = 10 Hz | 25°C | | 18 | 35 | | 18 | 25 | nV/√Hz |
| | | f = 1 kHz | 25°C | | 8 | 15 | | 8 | 12 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.5 | | | 0.5 | | μV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.7 | | | 0.7 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.6 | | | 0.6 | | fA/√Hz |
| | Gain-bandwidth product | f = 10 kHz, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 1.9 | | | 1.9 | | MHz |
| $\phi_m$ | Phase margin at unity gain | $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 47° | | | 47° | | |

†Full range is 0°C to 70°C.

NOTES: 4. Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A$ = 150°C extrapolated to $T_A$ = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

5. This parameter is tested on a sample basis for the TLC2202A and on all devices for the TLC2202B. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

## electrical characteristics at specified free-air temperature, $V_{DD\pm} = \pm 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLC2202I | | | UNIT |
|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 100 | 1000 | μV |
| | | | Full range | | | 1200 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | − 40°C to 85°C | | 0.5 | | μV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.001 | 0.005 | μV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 0.5 | | pA |
| | | | Full range | | | 150 | |
| $I_{IB}$ | Input bias current | | 25°C | | 1 | | pA |
| | | | Full range | | | 150 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | Full range | − 5 to 2.7 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $R_L = 10\ k\Omega$ | 25°C | 4.7 | 4.8 | | V |
| | | | Full range | 4.7 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | 25°C | − 4.7 | − 4.9 | | V |
| | | | Full range | − 4.7 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = \pm 4$ V, $R_L = 500\ k\Omega$ | 25°C | 400 | 560 | | V/mV |
| | | | Full range | 250 | | | |
| | | $V_O = \pm 4$ V, $R_L = 10\ k\Omega$ | 25°C | 90 | 100 | | |
| | | | Full range | 65 | | | |
| CMRR | Common-mode rejection ratio | $V_O = 0$, $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 25°C | 80 | 115 | | dB |
| | | | Full range | 80 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{DD\pm} / \Delta V_{IO}$) | $V_{DD\pm} = \pm 2.3$ V to $\pm 8$ V | 25°C | 80 | 110 | | dB |
| | | | Full range | 80 | | | |
| $I_{DD}$ | Supply current | $V_O = 0$, No load | 25°C | | 1.8 | 2.5 | mA |
| | | | Full range | | | 2.5 | |

## operating characteristics at specified free-air temperature, $V_{DD\pm} = \pm 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLC2202I | | | UNIT |
|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O = \pm 2.3$ V, $R_L = 10\ k\Omega$, $C_L = 100$ pF | 25°C | 2 | 2.7 | | V/μs |
| | | | Full range | 1.4 | | | |
| $V_n$ | Equivalent input noise voltage | f = 10 Hz | 25°C | | 18 | | nV/√Hz |
| | | f = 1 kHz | 25°C | | 8 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.5 | | μV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.7 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.6 | | fA/√Hz |
| | Gain-bandwidth product | f = 10 kHz, $R_L = 10\ k\Omega$, $C_L = 100$ pF | 25°C | | 1.9 | | MHz |
| $\phi_m$ | Phase margin at unity gain | $R_L = 10\ k\Omega$, $C_L = 100$ pF | 25°C | | 48° | | |

† Full range is −40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## electrical characteristics at specified free-air temperature, $V_{DD\pm} = \pm 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLC2202AI | | | TLC2202BI | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC}$ = 0, $R_S$ = 50 Ω | 25°C | | 80 | 500 | | 80 | 500 | µV |
| | | | Full range | | | 700 | | | 700 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | – 40°C to 85°C | | 0.5 | | | 0.5 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.001 | 0.005 | | 0.001 | 0.005 | µV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 0.5 | | | 0.5 | | pA |
| | | | Full range | | | 150 | | | 150 | |
| $I_{IB}$ | Input bias current | | 25°C | | 1 | | | 1 | | pA |
| | | | Full range | | | 150 | | | 150 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S$ = 50 Ω | Full range | – 5<br>to<br>2.7 | | | – 5<br>to<br>2.7 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $R_L$ = 10 kΩ | 25°C | 4.7 | 4.8 | | 4.7 | 4.8 | | V |
| | | | Full range | 4.7 | | | 4.7 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | 25°C | – 4.7 | – 4.9 | | – 4.7 | – 4.9 | | V |
| | | | Full range | – 4.7 | | | – 4.7 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O$ = ± 4 V,<br>$R_L$ = 500 kΩ | 25°C | 400 | 560 | | 400 | 560 | | V/mV |
| | | | Full range | 250 | | | 250 | | | |
| | | $V_O$ = ± 4 V,<br>$R_L$ = 10 kΩ | 25°C | 90 | 100 | | 90 | 100 | | |
| | | | Full range | 65 | | | 65 | | | |
| CMRR | Common-mode rejection ratio | $V_O$ = 0, $V_{IC}$ = $V_{ICR}$ min,<br>$R_S$ = 50 Ω | 25°C | 80 | 115 | | 80 | 115 | | dB |
| | | | Full range | 80 | | | 80 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{DD\pm} / \Delta V_{IO}$) | $V_{DD\pm}$ = ± 2.3 V to ± 8 V | 25°C | 80 | 110 | | 80 | 110 | | dB |
| | | | Full range | 80 | | | 80 | | | |
| $I_{DD}$ | Supply current | $V_O$ = 0, No load | 25°C | | 1.8 | 2.5 | | 1.8 | 2.5 | mA |
| | | | Full range | | | 2.5 | | | 2.5 | |

## operating characteristics at specified free-air temperature, $V_{DD\pm} = \pm 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLC2202AI | | | TLC2202BI | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O$ = ± 2.3 V,<br>$R_L$ = 10 kΩ,<br>$C_L$ = 100 pF | 25°C | 2 | 2.7 | | 2 | 2.7 | | V/µs |
| | | | Full range | 1.4 | | | 1.4 | | | |
| $V_n$ | Equivalent input noise voltage (see Note 5) | f = 10 Hz | 25°C | | 18 | 35 | | 18 | 25 | nV/√Hz |
| | | f = 1 kHz | 25°C | | 8 | 15 | | 8 | 12 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.5 | | | 0.5 | | µV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.7 | | | 0.7 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.6 | | | 0.6 | | fA/√Hz |
| | Gain-bandwidth product | f = 10 kHz,<br>$R_L$ = 10 kΩ,<br>$C_L$ = 100 pF | 25°C | | 1.9 | | | 1.9 | | MHz |
| $\phi_m$ | Phase margin at unity gain | $R_L$ = 10 kΩ,<br>$C_L$ = 100 pF | 25°C | | 48° | | | 48° | | |

†Full range is –40°C to 85°C.

NOTES: 4. Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A$ = 150°C extrapolated to $T_A$ = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

5. This parameter is tested on a sample basis for the TLC2202A and on all devices for the TLC2202B. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

## electrical characteristics at specified free-air temperature, $V_{DD}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLC2202I | | | UNIT |
|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC}$ = 0, $R_S$ = 50 Ω | 25°C | | 100 | 1000 | µV |
| | | | Full range | | | 1200 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | − 40°C to 85°C | | 0.5 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.001 | 0.005 | µV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 0.5 | | pA |
| | | | Full range | | | 150 | |
| $I_{IB}$ | Input bias current | | 25°C | | 1 | | pA |
| | | | Full range | | | 150 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S$ = 50 Ω | Full range | 0 to 2.7 | | | V |
| $V_{OH}$ | Maximum high-level output voltage | $R_L$ = 10 kΩ | 25°C | 4.7 | 4.8 | | V |
| | | | Full range | 4.7 | | | |
| $V_{OL}$ | Maximum low-level output voltage | $I_O$ = 0 | 25°C | | 0 | 50 | mV |
| | | | Full range | | | 50 | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O$ = 1 V to 4 V, $R_L$ = 500 kΩ | 25°C | 150 | 315 | | V/mV |
| | | | Full range | 100 | | | |
| | | $V_O$ = 1 V to 4 V, $R_L$ = 10 kΩ | 25°C | 25 | 55 | | |
| | | | Full range | 15 | | | |
| CMRR | Common-mode rejection ratio | $V_O$ = 0, $V_{IC}$ = $V_{ICR}$ min, $R_S$ = 50 Ω | 25°C | 75 | 110 | | dB |
| | | | Full range | 75 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{DD}$ / $\Delta V_{IO}$) | $V_{DD}$ = 4.6 V to 16 V | 25°C | 80 | 110 | | dB |
| | | | Full range | 80 | | | |
| $I_{DD}$ | Supply current | $V_O$ = 2.5 V, No load | 25°C | | 1.7 | 2.4 | mA |
| | | | Full range | | | 2.4 | |

## operating characteristics at specified free-air temperature, $V_{DD}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLC2202I | | | UNIT |
|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O$ = 0.5 V to 2.5 V, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | 1.8 | 2.5 | | V/µs |
| | | | Full range | 1.2 | | | |
| $V_n$ | Equivalent input noise voltage | f = 10 Hz | 25°C | | 18 | | nV/√Hz |
| | | f = 1 kHz | 25°C | | 8 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.5 | | µV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.7 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.6 | | fA/√Hz |
| | Gain-bandwidth product | f = 10 kHz, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 1.9 | | MHz |
| $\phi_m$ | Phase margin at unity gain | $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 47° | | |

†Full range is −40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A$ = 150°C extrapolated to $T_A$ = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## electrical characteristics at specified free-air temperature, $V_{DD}$ = 5 V (unless otherwise noted)

| | PARAMETER | TEST CONDITIONS | $T_A$† | TLC2202AI | | | TLC2202BI | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC}$ = 0, $R_S$ = 50 Ω | 25°C | | 80 | 500 | | 80 | 500 | µV |
| | | | Full range | | | 700 | | | 700 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | − 40°C to 85°C | | 0.5 | | | 0.5 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.001 | 0.005 | | 0.001 | 0.005 | µV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 0.5 | | | 0.5 | | pA |
| | | | Full range | | | 150 | | | 150 | |
| $I_{IB}$ | Input bias current | | 25°C | | 1 | | | 1 | | pA |
| | | | Full range | | | 150 | | | 150 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S$ = 50 Ω | Full range | 0<br>to<br>2.7 | | | 0<br>to<br>2.7 | | | V |
| $V_{OH}$ | Maximum high-level output voltage | $R_L$ = 10 kΩ | 25°C | 4.7 | 4.8 | | 4.7 | 4.8 | | V |
| | | | Full range | 4.7 | | | 4.7 | | | |
| $V_{OL}$ | Maximum low-level output voltage | $I_O$ = 0 | 25°C | | 0 | 50 | | 0 | 50 | mV |
| | | | Full range | | | 50 | | | 50 | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O$ = 1 V to 4 V, $R_L$ = 500 kΩ | 25°C | 150 | 315 | | 150 | 315 | | V/mV |
| | | | Full range | 100 | | | 100 | | | |
| | | $V_O$ = 1 V to 4 V, $R_L$ = 10 kΩ | 25°C | 25 | 55 | | 25 | 55 | | |
| | | | Full range | 15 | | | 15 | | | |
| CMRR | Common-mode rejection ratio | $V_O$ = 0, $V_{IC}$ = $V_{ICR}$ min, $R_S$ = 50 Ω | 25°C | 75 | 110 | | 75 | 110 | | dB |
| | | | Full range | 75 | | | 75 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{DD} / \Delta V_{IO}$) | $V_{DD}$ = 4.6 V to 16 V | 25°C | 80 | 110 | | 80 | 110 | | dB |
| | | | Full range | 80 | | | 80 | | | |
| $I_{DD}$ | Supply current | $V_O$ = 2.5 V, No load | 25°C | | 1.7 | 2.4 | | 1.7 | 2.4 | mA |
| | | | Full range | | | 2.4 | | | 2.4 | |

## operating characteristics at specified free-air temperature, $V_{DD}$ = 5 V (unless otherwise noted)

| | PARAMETER | TEST CONDITIONS | $T_A$† | TLC2202AI | | | TLC2202BI | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O$ = 0.5 V to 2.5 V, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | 1.8 | 2.5 | | 1.8 | 2.5 | | V/µs |
| | | | Full range | 1.2 | | | 1.2 | | | |
| $V_n$ | Equivalent input noise voltage (see Note 5) | f = 10 Hz | 25°C | | 18 | 35 | | 18 | 25 | nV/√Hz |
| | | f = 1 kHz | 25°C | | 8 | 15 | | 8 | 12 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.5 | | | 0.5 | | µV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.7 | | | 0.7 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.6 | | | 0.6 | | fA/√Hz |
| | Gain-bandwidth product | f = 10 kHz, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 1.9 | | | 1.9 | | MHz |
| $\varphi_m$ | Phase margin at unity gain | $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 47° | | | 47° | | |

† Full range is −40°C to 85°C.

NOTES: 4. Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A$ = 150°C extrapolated to $T_A$ = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

5. This parameter is tested on a sample basis for the TLC2202A and on all devices for the TLC2202B. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

## electrical characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLC2202M | | | UNIT |
|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC}$ = 0, $R_S$ = 50 Ω | 25°C | | 100 | 1000 | µV |
| | | | Full range | | | 1250 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | − 55°C to 125°C | | 0.5 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.001 | 0.005* | µV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 0.5 | | pA |
| | | | Full range | | | 500 | |
| $I_{IB}$ | Input bias current | | 25°C | | 1 | | pA |
| | | | Full range | | | 500 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S$ = 50 Ω | Full range | − 5 to 2.7 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $R_L$ = 10 kΩ | 25°C | 4.7 | 4.8 | | V |
| | | | Full range | 4.7 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | 25°C | − 4.7 | − 4.9 | | V |
| | | | Full range | − 4.7 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O$ = ± 4 V, $R_L$ = 500 kΩ | 25°C | 400 | 560 | | V/mV |
| | | | Full range | 200 | | | |
| | | $V_O$ = ± 4 V, $R_L$ = 10 kΩ | 25°C | 90 | 100 | | |
| | | | Full range | 45 | | | |
| CMRR | Common-mode rejection ratio | $V_O$ = 0, $V_{IC}$ = $V_{ICR}$ min, $R_S$ = 50 Ω | 25°C | 80 | 115 | | dB |
| | | | Full range | 80 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{DD\pm} / \Delta V_{IO}$) | $V_{DD\pm}$ = ± 2.3 V to ± 8 V | 25°C | 80 | 110 | | dB |
| | | | Full range | 80 | | | |
| $I_{DD}$ | Supply current | $V_O$ = 0, No load | 25°C | | 1.8 | 2.5 | mA |
| | | | Full range | | | 2.5 | |

## operating characteristics at specified free-air temperature, $V_{DD\pm}$ = ± 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLC2202M | | | UNIT |
|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O$ = ± 2.3 V, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | 2 | 2.7 | | V/µs |
| | | | Full range | 1.3 | | | |
| $V_n$ | Equivalent input noise voltage | f = 10 Hz | 25°C | | 18 | | nV/√Hz |
| | | f = 1 kHz | 25°C | | 8 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.5 | | µV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.7 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.6 | | fA/√Hz |
| | Gain-bandwidth product | f = 10 kHz, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 1.9 | | MHz |
| $\phi_m$ | Phase margin at unity gain | $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 48° | | |

*On products compliant to MIL-STD-883, Class B, this parameter is not production-tested.

†Full range is −55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A$ = 150°C extrapolated to $T_A$ = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## electrical characteristics at specified free-air temperature, $V_{DD\pm} = \pm 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$[†] | TLC2202AM | | | TLC2202BM | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 80 | 500 | | 80 | 500 | μV |
| | | | Full range | | | 750 | | | 750 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | – 55°C to 125°C | | 0.5 | | | 0.5 | | μV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.001 | 0.005* | | 0.001 | 0.005* | μV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 0.5 | | | 0.5 | | pA |
| | | | Full range | | | 500 | | | 500 | |
| $I_{IB}$ | Input bias current | | 25°C | | 1 | | | 1 | | pA |
| | | | Full range | | | 500 | | | 500 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | Full range | – 5 to 2.7 | | | – 5 to 2.7 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $R_L = 10\ \text{k}\Omega$ | 25°C | 4.7 | 4.8 | | 4.7 | 4.8 | | V |
| | | | Full range | 4.7 | | | 4.7 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | 25°C | – 4.7 | – 4.9 | | – 4.7 | – 4.9 | | V |
| | | | Full range | – 4.7 | | | – 4.7 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = \pm 4$ V, $R_L = 500\ \text{k}\Omega$ | 25°C | 400 | 560 | | 400 | 560 | | V/mV |
| | | | Full range | 200 | | | 200 | | | |
| | | $V_O = \pm 4$ V, $R_L = 10\ \text{k}\Omega$ | 25°C | 90 | 100 | | 90 | 100 | | |
| | | | Full range | 45 | | | 45 | | | |
| CMRR | Common-mode rejection ratio | $V_O = 0$, $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 25°C | 80 | 115 | | 80 | 115 | | dB |
| | | | Full range | 80 | | | 80 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{DD\pm} / \Delta V_{IO}$) | $V_{DD\pm} = \pm 2.3$ V to $\pm 8$ V | 25°C | 80 | 110 | | 80 | 110 | | dB |
| | | | Full range | 80 | | | 80 | | | |
| $I_{DD}$ | Supply current | $V_O = 0$, No load | 25°C | | 1.8 | 2.5 | | 1.8 | 2.5 | mA |
| | | | Full range | | | 2.5 | | | 2.5 | |

## operating characteristics at specified free-air temperature, $V_{DD\pm} = \pm 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$[†] | TLC2202AM | | | TLC2202BM | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O = \pm 2.3$ V, $R_L = 10\ \text{k}\Omega$, $C_L = 100$ pF | 25°C | 2 | 2.7 | | 2 | 2.7 | | V/μs |
| | | | Full range | 1.3 | | | 1.3 | | | |
| $V_n$ | Equivalent input noise voltage (see Note 5) | f = 10 Hz | 25°C | | 18 | 35* | | 18 | 25* | nV/$\sqrt{\text{Hz}}$ |
| | | f = 1 kHz | 25°C | | 8 | 15* | | 8 | 12* | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.5 | | | 0.5 | | μV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.7 | | | 0.7 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.6 | | | 0.6 | | fA/$\sqrt{\text{Hz}}$ |
| | Gain-bandwidth product | f = 10 kHz, $R_L = 10\ \text{k}\Omega$, $C_L = 100$ pF | 25°C | | 1.9 | | | 1.9 | | MHz |
| $\phi_m$ | Phase margin at unity gain | $R_L = 10\ \text{k}\Omega$, $C_L = 100$ pF | 25°C | | 48° | | | 48° | | |

*On products compliant to MIL-STD-883, Class B, this parameter is not production-tested.

[†] Full range is –55°C to 125°C.

NOTES: 4. Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

5. This parameter is tested on a sample basis for the TLC2202A and on all devices for the TLC2202B. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

## electrical characteristics at specified free-air temperature, $V_{DD}$ = 5 V (unless otherwise noted)

| | PARAMETER | TEST CONDITIONS | $T_A$[†] | TLC2202M | | | UNIT |
|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC}$ = 0, $R_S$ = 50 Ω | 25°C | | 100 | 1000 | μV |
| | | | Full range | | | 1250 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | – 55°C to 125°C | | 0.5 | | μV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.001 | 0.005[*] | μV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 0.5 | | pA |
| | | | Full range | | | 500 | |
| $I_{IB}$ | Input bias current | | 25°C | | 1 | | pA |
| | | | Full range | | | 500 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S$ = 50 Ω | Full range | 0 to 2.7 | | | V |
| $V_{OH}$ | Maximum high-level output voltage | $R_L$ = 10 kΩ | 25°C | 4.7 | 4.8 | | V |
| | | | Full range | 4.7 | | | |
| $V_{OL}$ | Maximum low-level output voltage | $I_O$ = 0 | 25°C | | 0 | 50 | mV |
| | | | Full range | | | 50 | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O$ = 1 V to 4 V, $R_L$ = 500 kΩ | 25°C | 150 | 315 | | V/mV |
| | | | Full range | 75 | | | |
| | | $V_O$ = 1 V to 4 V, $R_L$ = 10 kΩ | 25°C | 25 | 55 | | |
| | | | Full range | 10 | | | |
| CMRR | Common-mode rejection ratio | $V_{IC}$ = $V_{ICR}$ min, $R_S$ = 50 Ω | 25°C | 75 | 110 | | dB |
| | | | Full range | 75 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{DD} / \Delta V_{IO}$) | $V_{DD}$ = 4.6 V to 16 V | 25°C | 80 | 110 | | dB |
| | | | Full range | 80 | | | |
| $I_{DD}$ | Supply current | $V_O$ = 2.5 V, No load | 25°C | | 1.7 | 2.4 | mA |
| | | | Full range | | | 2.4 | |

## operating characteristics at specified free-air temperature, $V_{DD}$ = 5 V (unless otherwise noted)

| | PARAMETER | TEST CONDITIONS | $T_A$[†] | TLC2202M | | | UNIT |
|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O$ = 0.5 V to 2.5 V, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | 1.8 | 2.5 | | V/μs |
| | | | Full range | 1.1 | | | |
| $V_n$ | Equivalent input noise voltage | f = 10 Hz | 25°C | | 18 | | nV/$\sqrt{\text{Hz}}$ |
| | | f = 1 kHz | 25°C | | 8 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.5 | | μV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.7 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.6 | | fA/$\sqrt{\text{Hz}}$ |
| | Gain-bandwidth product | f = 10 kHz, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 1.9 | | MHz |
| $\phi_m$ | Phase margin at unity gain | $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 47° | | |

[*] On products compliant to MIL-STD-883, Class B, this parameter is not production-tested.

[†] Full range is −55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A$ = 150°C extrapolated to $T_A$ = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## electrical characteristics at specified free-air temperature, $V_{DD}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLC2202AM | | | TLC2202BM | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC}$ = 0, $R_S$ = 50 Ω | 25°C | | 80 | 500 | | 80 | 500 | µV |
| | | | Full range | | | 750 | | | 750 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | – 55°C to 125°C | | 0.5 | | | 0.5 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.001 | 0.005* | | 0.001 | 0.005* | µV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 0.5 | | | 0.5 | | pA |
| | | | Full range | | | 500 | | | 500 | |
| $I_{IB}$ | Input bias current | | 25°C | | 1 | | | 1 | | pA |
| | | | Full range | | | 500 | | | 500 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S$ = 50 Ω | Full range | 0 to 2.7 | | | 0 to 2.7 | | | V |
| $V_{OH}$ | Maximum high-level output voltage | $R_L$ = 10 kΩ | 25°C | 4.7 | 4.8 | | 4.7 | 4.8 | | V |
| | | | Full range | 4.7 | | | 4.7 | | | |
| $V_{OL}$ | Maximum low-level output voltage | $I_O$ = 0 | 25°C | | 0 | 50 | | 0 | 50 | mV |
| | | | Full range | | | 50 | | | 50 | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O$ = 1 V to 4 V, $R_L$ = 500 kΩ | 25°C | 150 | 315 | | 150 | 315 | | V/mV |
| | | | Full range | 75 | | | 75 | | | |
| | | $V_O$ = 1 V to 4 V, $R_L$ = 10 kΩ | 25°C | 25 | 55 | | 25 | 55 | | |
| | | | Full range | 10 | | | 10 | | | |
| CMRR | Common-mode rejection ratio | $V_{IC}$ = $V_{ICR}$ min, $R_S$ = 50 Ω | 25°C | 75 | 110 | | 75 | 110 | | dB |
| | | | Full range | 75 | | | 75 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{DD} / \Delta V_{IO}$) | $V_{DD}$ = 4.6 V to 16 V | 25°C | 80 | 110 | | 80 | 110 | | dB |
| | | | Full range | 80 | | | 80 | | | |
| $I_{DD}$ | Supply current | $V_O$ = 2.5 V, No load | 25°C | | 1.7 | 2.4 | | 1.7 | 2.4 | mA |
| | | | Full range | | | 2.4 | | | 2.4 | |

## operating characteristics at specified free-air temperature, $V_{DD}$ = 5V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLC2202AM | | | TLC2202BM | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O$ = 0.5 V to 2.5 V, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | 1.8 | 2.5 | | 1.8 | 2.5 | | V/µs |
| | | | Full range | 1.1 | | | 1.1 | | | |
| $V_n$ | Equivalent input noise voltage (see Note 5) | f = 10 Hz | 25°C | | 18 | 35* | | 18 | 25* | nV/√Hz |
| | | f = 1 kHz | 25°C | | 8 | 15* | | 8 | 12* | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.5 | | | 0.5 | | µV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.7 | | | 0.7 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.6 | | | 0.6 | | fA/√Hz |
| | Gain-bandwidth product | f = 10 kHz, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 1.9 | | | 1.9 | | MHz |
| $\phi_m$ | Phase margin at unity gain | $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 47° | | | 47° | | |

*On products compliant to MIL-STD-883, Class B, this parameter is not production-tested.

†Full range is –55°C to 125°C.

NOTES: 4. Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A$ = 150°C extrapolated to $T_A$ = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

5. This parameter is tested on a sample basis for the TLC2202A and on all devices for the TLC2202B. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

## PARAMETER MEASUREMENT INFORMATION

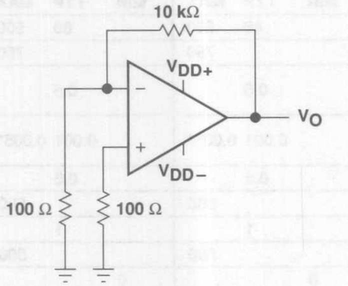
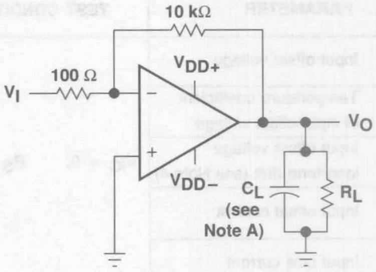
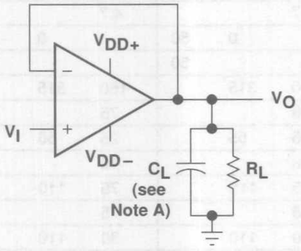


Figure 1. Noise Voltage Test Circuit



NOTE A: $C_L$ includes fixture capacitance.

Figure 2. Phase Margin Test Circuit



NOTE A: $C_L$ includes fixture capacitance.

Figure 3. Slew Rate Test Circuit

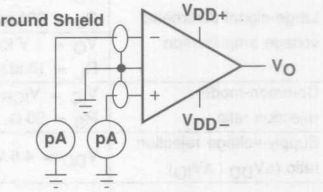


Figure 4. Input Bias and Offset Current Test Circuit

### typical values

Typical values as presented in this data sheet represent the median (50% point) of device parametric performance.

### input bias and offset current

At the picoamp bias current level typical of the TLC2202, TLC2202A, and TLC2202B, accurate measurement of the bias current becomes difficult. Not only does this measurement require a picoammeter, but test socket leakages can easily exceed the actual device bias currents. To measure these small currents, Texas Instruments uses a two-step process. The socket leakage is measured using picoammeters with bias voltages applied but with no device in the socket. The device is then inserted in the socket and a second test measuring both the socket leakage and the device input bias current is performed. The two measurements are then subtracted algebraically to determine the bias current of the device.

### noise

Texas Instruments offers automated production noise testing to meet individual applications requirements. Noise voltage at f = 10 Hz and f = 1 kHz is 100% tested on every TLC2202B device, while lot sample testing is performed on the TLC2202A. For other noise test requirements, please contact the factory.

## TYPICAL CHARACTERISTICS

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| $V_{IO}$ | Input offset voltage | Distribution | 5 |
| $I_{IB}$ | Input bias current | vs Common-mode voltage | 6 |
| | | vs Temperature | 7 |
| $V_{OM}$ | Maximum peak output voltage | vs Output current | 8, 9 |
| | | vs Temperature | 10 |
| $V_{O(PP)}$ | Maximum peak-to-peak output voltage | vs Frequency | 11 |
| $V_{OH}$ | High-level output voltage | vs Frequency | 12 |
| | | vs Current | 13 |
| | | vs Temperature | 14 |
| $V_{OL}$ | Low-level output voltage | vs Output current | 15 |
| | | vs Temperature | 16 |
| $A_{VD}$ | Differential voltage amplification | vs Frequency | 17 |
| | | vs Temperature | 18 |
| $I_{OS}$ | Short-circuit output current | vs Supply voltage | 19 |
| | | vs Temperature | 20 |
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| | | vs Temperature | 24 |
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| SR | Slew rate | vs Supply voltage | 29 |
| | | vs Temperature | 30 |
| | Noise voltage (referred to input) | 0.1 to 1 Hz | 31 |
| | | 0.1 to 10 Hz | 32 |
| | Gain-bandwidth product | vs Supply voltage | 33 |
| | | vs Temperature | 34 |
| $\phi_m$ | Phase margin | vs Supply voltage | 35 |
| | | vs Temperature | 36 |
| | Phase shift | vs Frequency | 17 |

## TYPICAL CHARACTERISTICS†

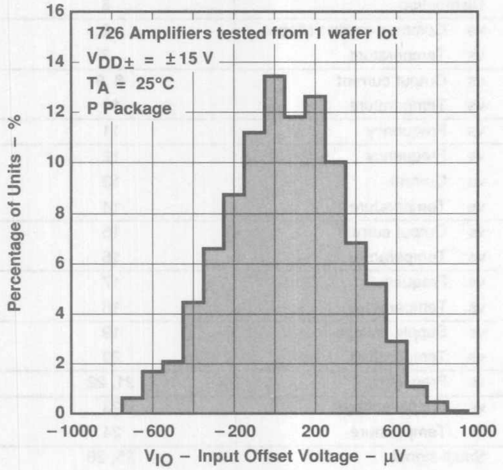
TLC2202
DISTRIBUTION OF
INPUT OFFSET VOLTAGE

Figure 5

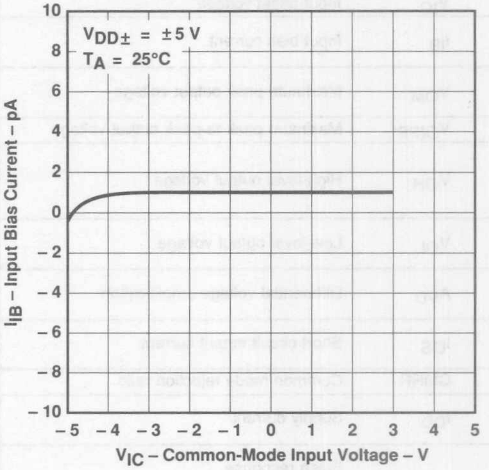
INPUT BIAS CURRENT
vs
COMMON-MODE INPUT VOLTAGE

Figure 6

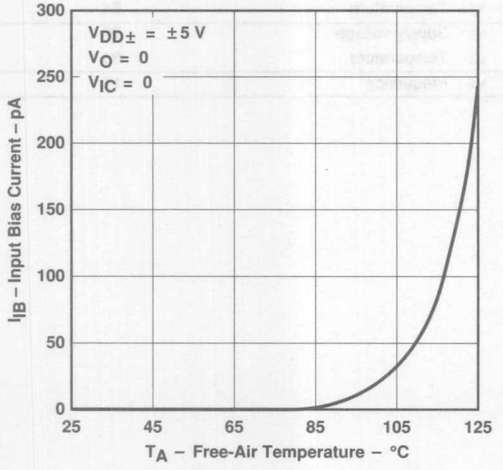
INPUT BIAS CURRENT
vs
FREE-AIR TEMPERATURE

Figure 7

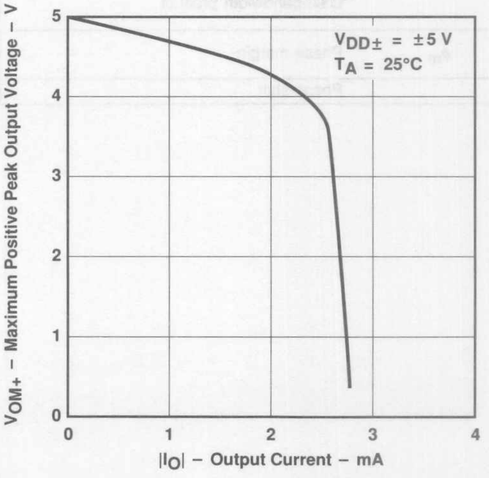
MAXIMUM POSITIVE PEAK
OUTPUT VOLTAGE
vs
OUTPUT CURRENT

Figure 8

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†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

### MAXIMUM NEGATIVE PEAK OUTPUT VOLTAGE vs OUTPUT CURRENT

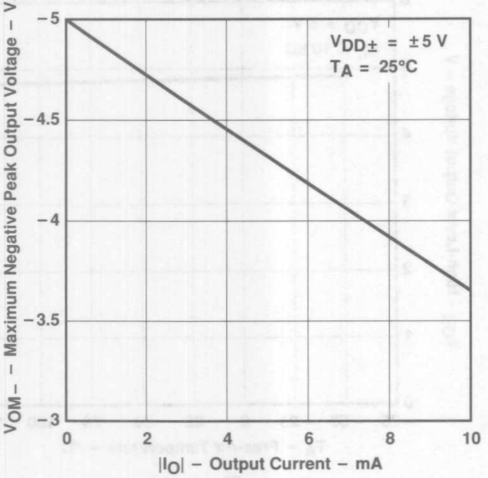

Figure 9

### MAXIMUM PEAK OUTPUT VOLTAGE vs FREE-AIR TEMPERATURE

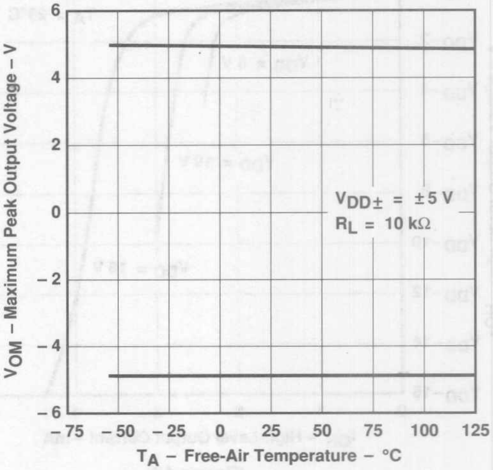

Figure 10

### MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE vs FREQUENCY

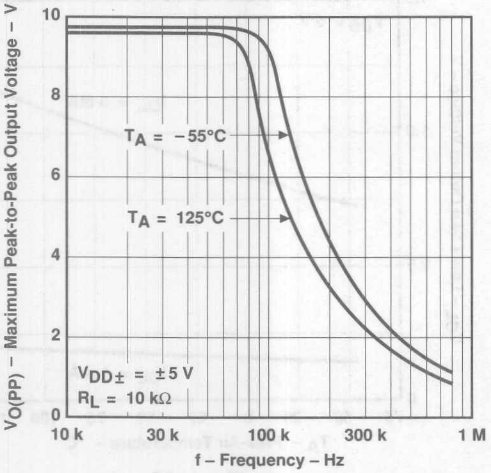

Figure 11

### HIGH-LEVEL OUTPUT VOLTAGE vs FREQUENCY

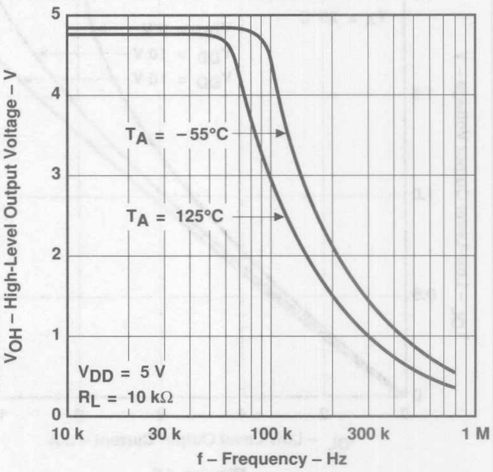

Figure 12

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† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

HIGH-LEVEL OUTPUT VOLTAGE
vs
HIGH-LEVEL OUTPUT CURRENT

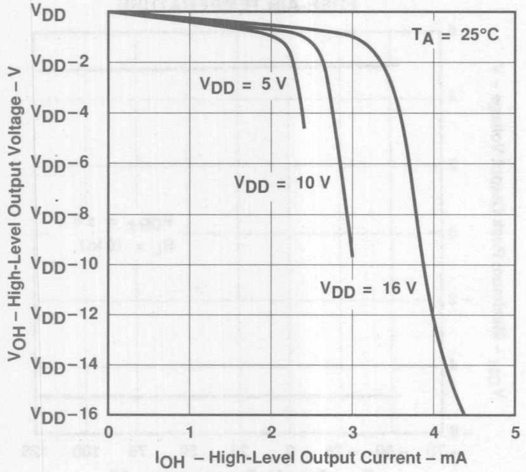

Figure 13

HIGH-LEVEL OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE

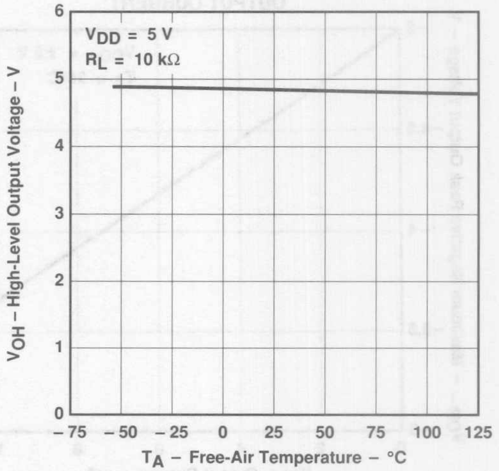

Figure 14

LOW-LEVEL OUTPUT VOLTAGE
vs
LOW-LEVEL OUTPUT CURRENT

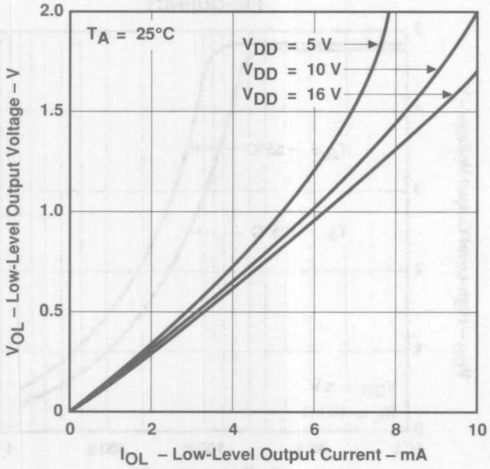

Figure 15

LOW-LEVEL OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE

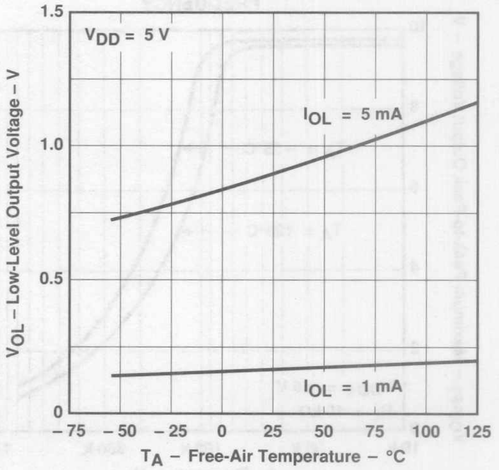

Figure 16

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†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

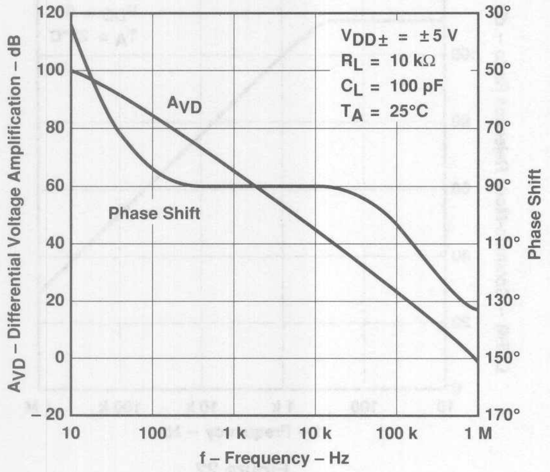
LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT vs FREQUENCY

Figure 17

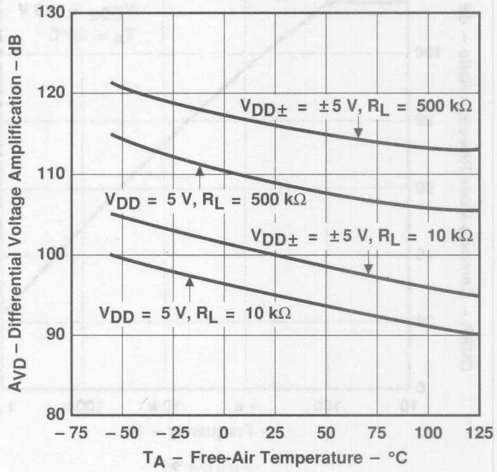
LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION vs FREE-AIR TEMPERATURE

Figure 18

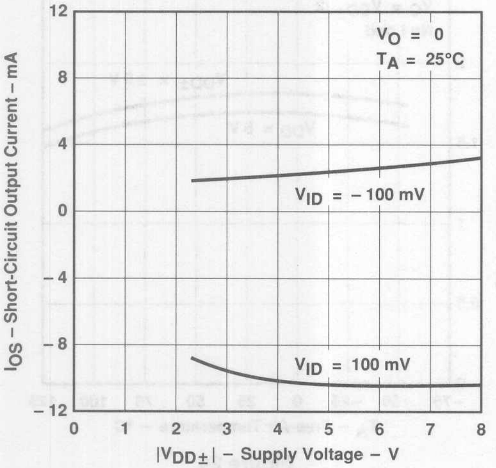
SHORT-CIRCUIT OUTPUT CURRENT vs SUPPLY VOLTAGE

Figure 19

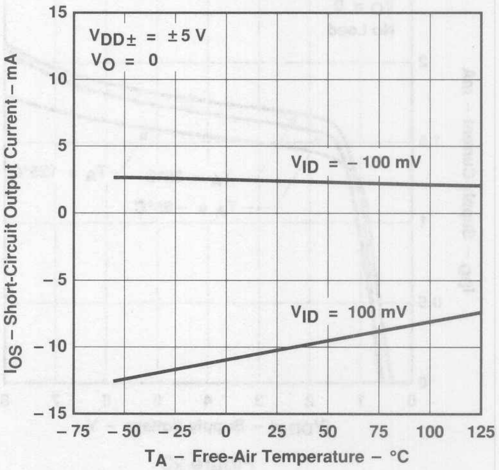
SHORT-CIRCUIT OUTPUT CURRENT vs FREE-AIR TEMPERATURE

Figure 20

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† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS[†]

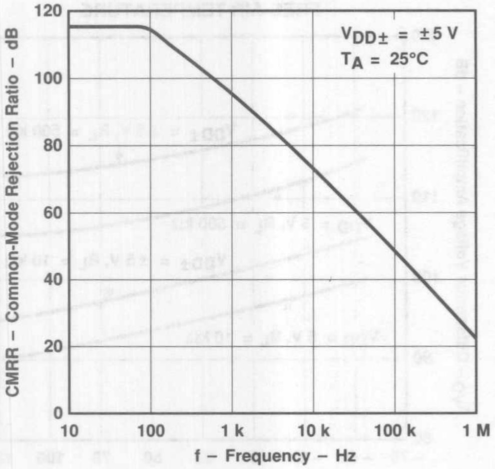
COMMON-MODE REJECTION RATIO
vs
FREQUENCY

Figure 21

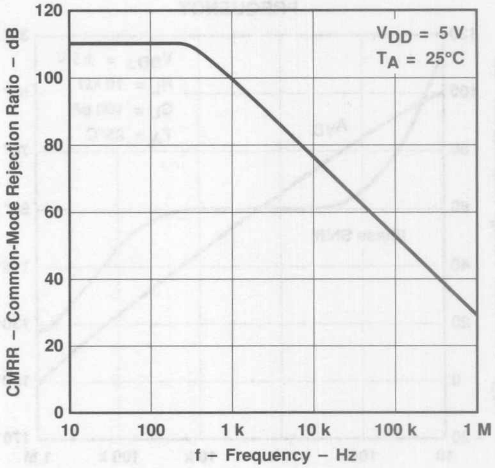
COMMON-MODE REJECTION RATIO
vs
FREQUENCY

Figure 22

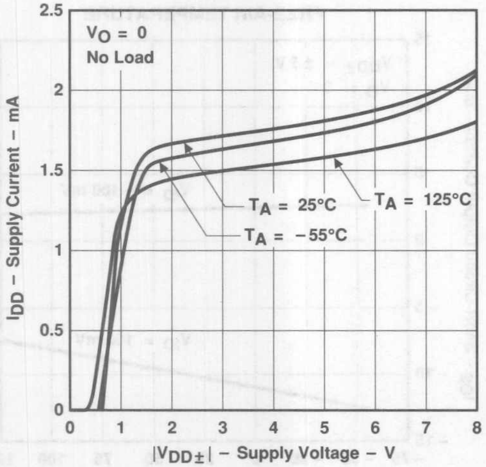
SUPPLY CURRENT
vs
SUPPLY VOLTAGE

Figure 23

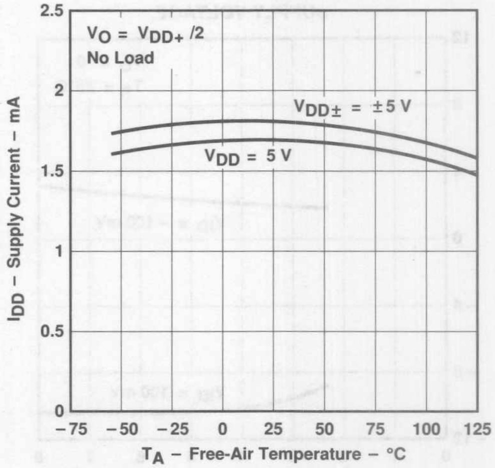
SUPPLY CURRENT
vs
FREE-AIR TEMPERATURE

Figure 24

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[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS

**VOLTAGE-FOLLOWER
SMALL-SIGNAL
PULSE RESPONSE**

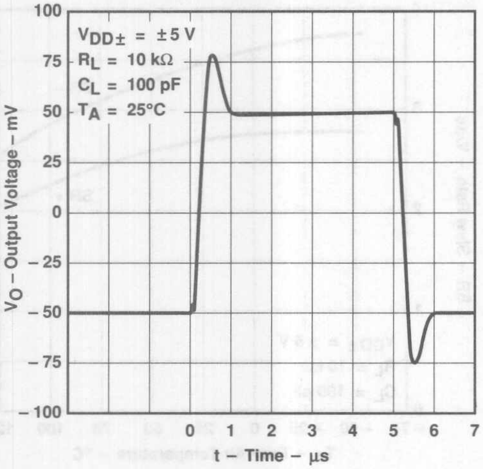

Figure 25

**VOLTAGE-FOLLOWER
SMALL-SIGNAL
PULSE RESPONSE**

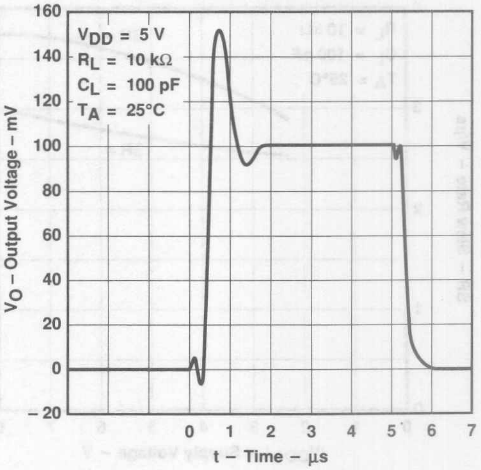

Figure 26

**VOLTAGE-FOLLOWER
LARGE-SIGNAL
PULSE RESPONSE**

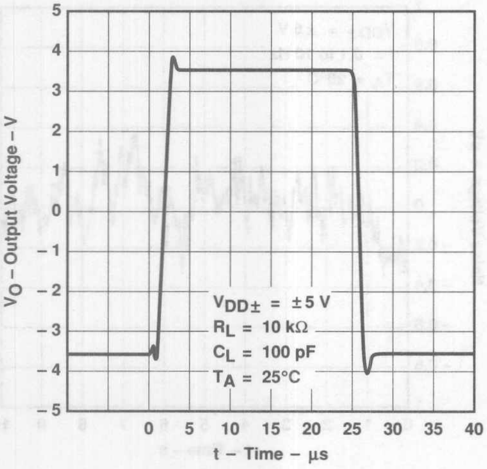

Figure 27

**VOLTAGE-FOLLOWER
LARGE-SIGNAL
PULSE RESPONSE**

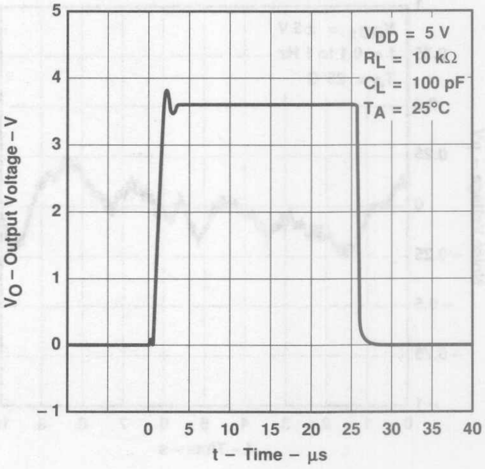

Figure 28

## TYPICAL CHARACTERISTICS†

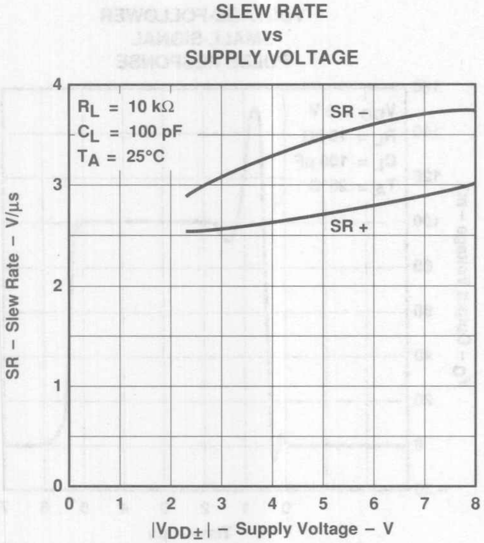

Figure 29

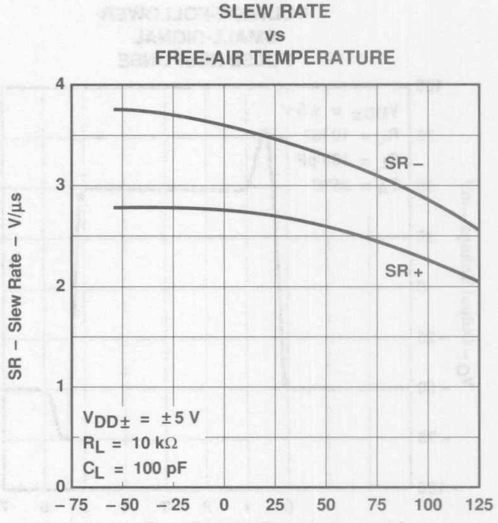

Figure 30

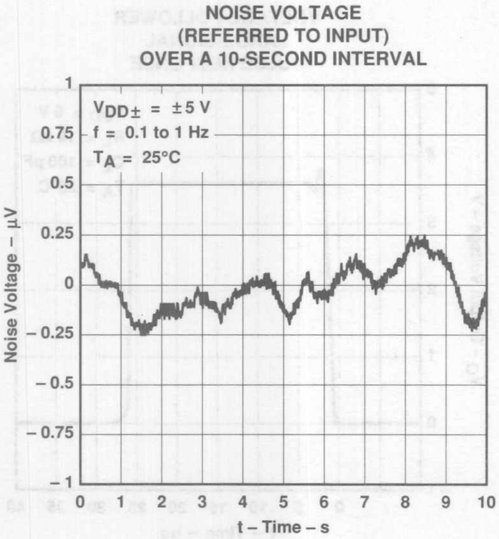

Figure 31

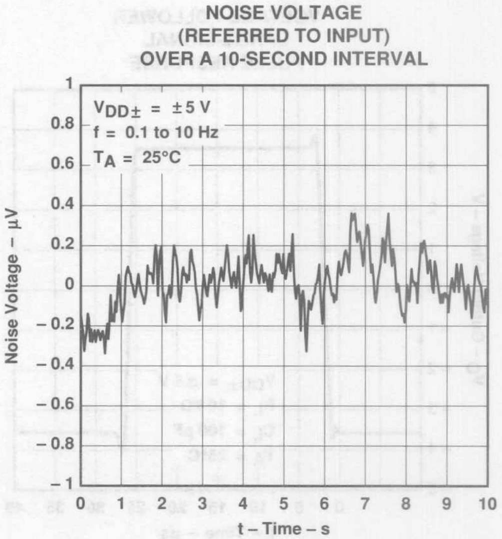

Figure 32

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†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS[†]

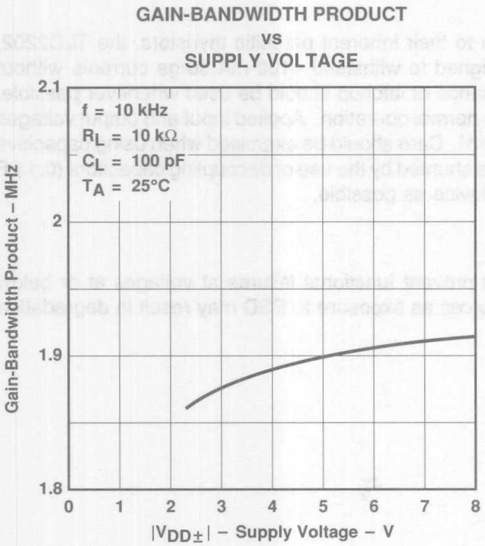

Figure 33

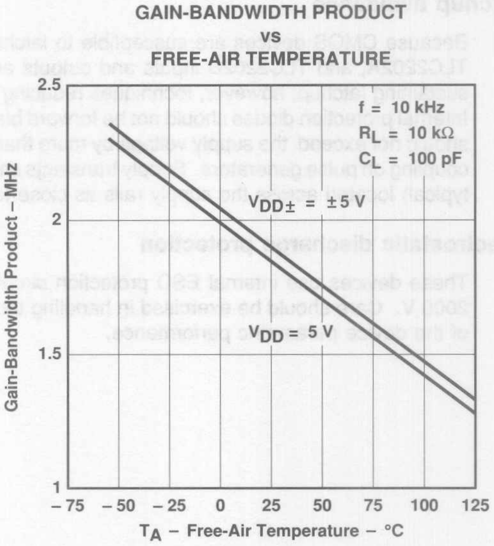

Figure 34

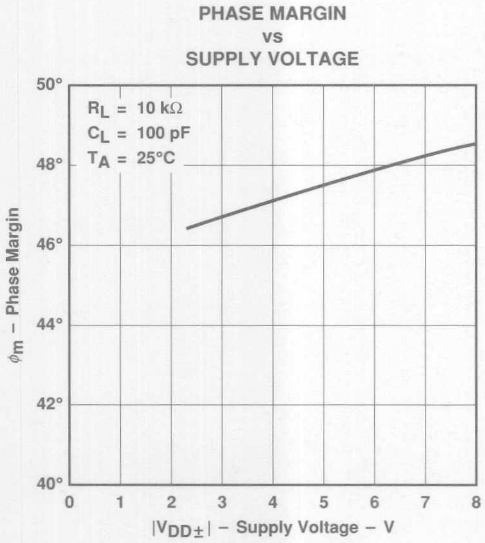

Figure 35

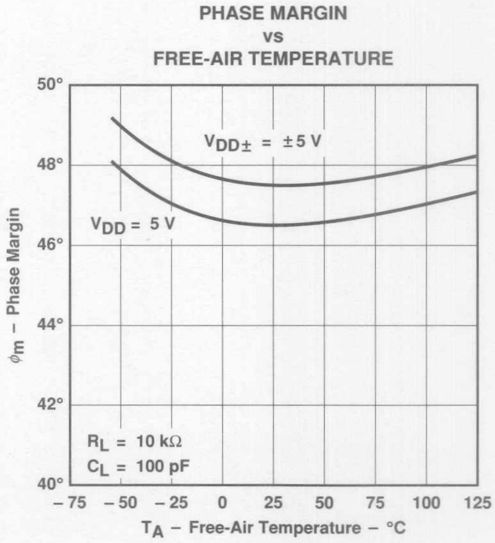

Figure 36

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[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL APPLICATION DATA

### latchup avoidance

Because CMOS devices are susceptible to latchup due to their inherent parasitic thyristors, the TLC2202, TLC2202A, and TLC2202B inputs and outputs are designed to withstand −100-mA surge currents without sustaining latchup; however, techniques reducing the chance of latchup should be used whenever possible. Internal protection diodes should not be forward biased in normal operation. Applied input and output voltages should not exceed the supply voltage by more than 300 mV. Care should be exercised when using capacitive coupling on pulse generators. Supply transients should be shunted by the use of decoupling capacitors (0.1 μF typical) located across the supply rails as close to the device as possible.

### electrostatic discharge protection

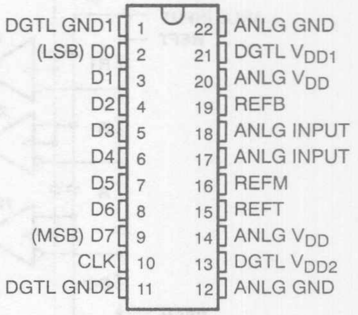
These devices use internal ESD protection circuits that prevent functional failures at voltages at or below 2000 V. Care should be exercised in handling these devices as exposure to ESD may result in degradation of the device parametric performance.

# TLC5502-5
# 8-BIT ANALOG-TO-DIGITAL CONVERTER

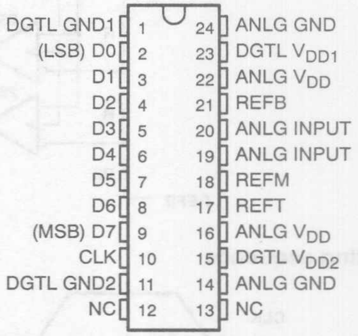
D3638, JANUARY 1991

- **LinEPIC™ 1-μm CMOS Process**
- **8-Bit Resolution**
- **Linearity Error . . . ±0.4% Max**
- **Maximum Conversion Rate . . . 20 MHz Typ**
  **. . . 10 MHz Min**
- **Analog Input Voltage Range . . . 0 V to $V_{CC}$**
- **TTL Digital I/O Level**
- **Low Power Consumption . . . 150 mW Typ**
- **5-V Single-Supply Operation**

N PACKAGE
(TOP VIEW)



DW PACKAGE
(TOP VIEW)



NC – No internal connection

## description

The TLC5502-5 is a low-power ultra-high-speed video-band analog-to-digital converter that uses the LinEPIC™ CMOS process. It utilizes the full-parallel comparison (flash method) for high-speed conversion. It converts wide-band analog signals (such as a video signal) to a digital signal at a sampling rate of dc to 25 MHz. Because of such high-speed capability, the TLC5502-5 is suitable for digital video applications such as digital TV, video processing with a computer, or radar signal processing.

Separate analog and digital supply pins are provided to reduce coupling between the high-speed digital switching sections and the lower-frequency analog signal comparators. This pin partitioning minimizes crosstalk and unwanted spurious signals.

The TLC5502-5 is characterized for operation from 0°C to 70°C.

LinEPIC is a trademark of Texas Instruments Incorporated.

PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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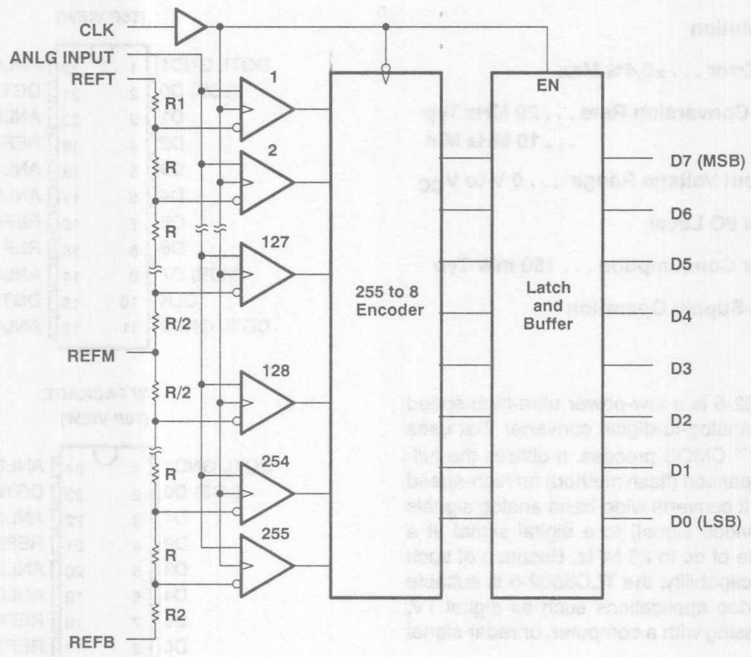
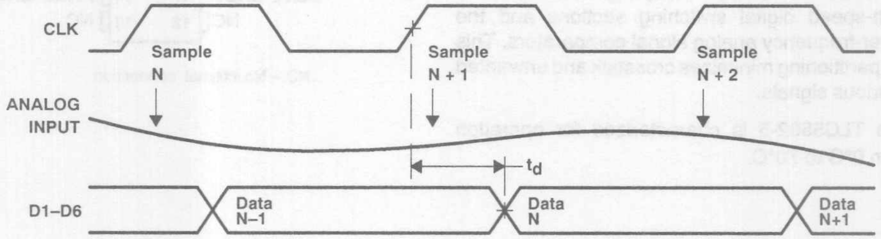
## functional block diagram

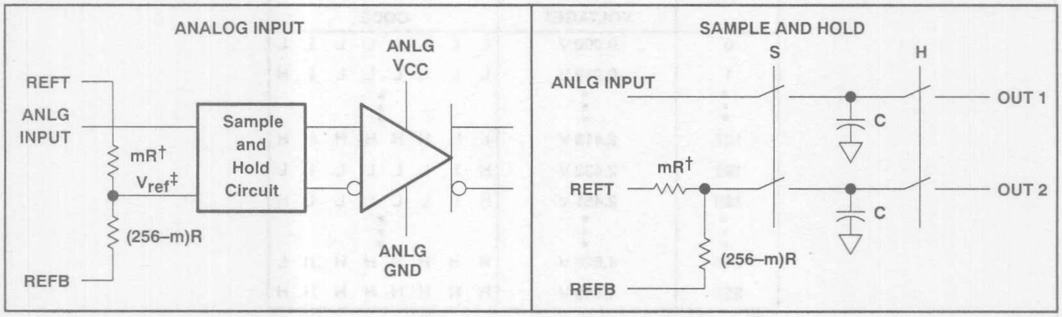


## operating sequence



Following the operating sequence above, the rising edge of the clock samples the analog input (sample N) at time $t_N$ and latches sample N – 1 at the output. Sample N is encoded to eight digital lines on the next falling edge of the clock and then the following high clock level latches these eight bits to the outputs (with a delay $t_d$) and acquires sample N + 1. Conversion is completed in one clock cycle and continues the sequence for the next cycle.

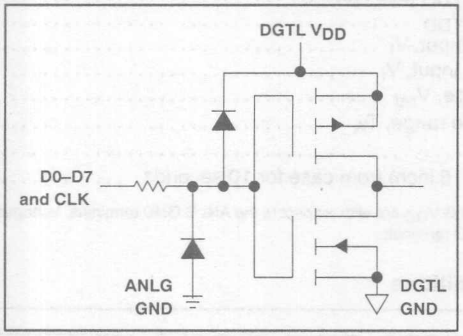
## equivalents of analog input circuit



† m = comparator position along the resistor string.

‡ $$V_{ref}{}' = V_{ref}\left[1 - \frac{m}{256}\right]$$

## equivalent of digital input circuit



FUNCTION TABLE

| STEP | ANALOG INPUT VOLTAGE† | DIGITAL OUTPUT CODE |
|---|---|---|
| 0 | 0.000 V | L L L L L L L L |
| 1 | 0.019 V | L L L L L L L H |
| ⋮ | ⋮ | ⋮ |
| 127 | 2.413 V | L H H H H H H H |
| 128 | 2.432 V | H L L L L L L L |
| 129 | 2.451 V | H L L L L L L H |
| ⋮ | ⋮ | ⋮ |
| 254 | 4.826 V | H H H H H H H L |
| 255 | 4.845 V | H H H H H H H H |

† These values are based on the assumption that $V_{refB}$ and $V_{refT}$ have been adjusted so that the voltage at the transition from digital 0 to 1 ($V_{ZT}$) is 0 V and the transition to full scale ($V_{FT}$) is 4.8545 V. 1 LSB = 19 mV.

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage range, ANLG $V_{DD}$ (see Note 1) .......................................... – 0.5 V to 7 V
Supply voltage range, DGTL $V_{DD}$ .......................................................... – 0.5 V to 7 V
Input voltage range at digital input, $V_I$ ................................................... – 0.5 V to 7 V
Input voltage range at analog input, $V_I$ .................................. – 0.5 V to ANLG $V_{DD}$ + 0.5 V
Analog reference voltage range, $V_{ref}$ .................................. – 0.5 V to ANLG $V_{DD}$ + 0.5 V
Operating free-air temperature range, $T_A$ ............................................... 0°C to 70°C
Storage temperature range ................................................................. – 55°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds ................................ 260°C

NOTE 1: Voltages at analog inputs and ANLG $V_{DD}$ are with respect to the ANLG GND terminals. Voltages at the digital outputs and DGTL $V_{DD}$ are with respect to the DGTL GND terminals.

## recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|
| Supply voltage, ANLG $V_{DD}$ | 4.75 | 5 | 5.25 | V |
| Supply voltage, DGTL $V_{DD}$ | 4.75 | 5 | 5.25 | V |
| High-level input voltage, $V_{IH}$ | 2 | | | V |
| Low-level input voltage, $V_{IL}$ | | | 0.8 | V |
| Input voltage at analog input, $V_I$ | 0 | | 5 | V |
| Analog reference voltage (top side), $V_{refT}$ | | ANLG $V_{DD}$ | | V |
| Analog reference voltage (bottom side), $V_{refB}$ | | 0 | | V |
| Differential reference voltage, $V_{refT} - V_{refB}$ | | 5 | | V |
| High-level output current, $I_{OH}$ | | | – 400 | μA |
| Low-level output current, $I_{OL}$ | | | 4 | mA |
| Clock pulse duration, high-level or low-level, $t_{wH}$ or $t_{wL}$ | 50 | | | ns |
| Operating free-air temperature, $T_A$ | 0 | | 70 | °C |

## electrical characteristics over operating supply voltage range, $T_A$ = 25°C (unless otherwise noted)

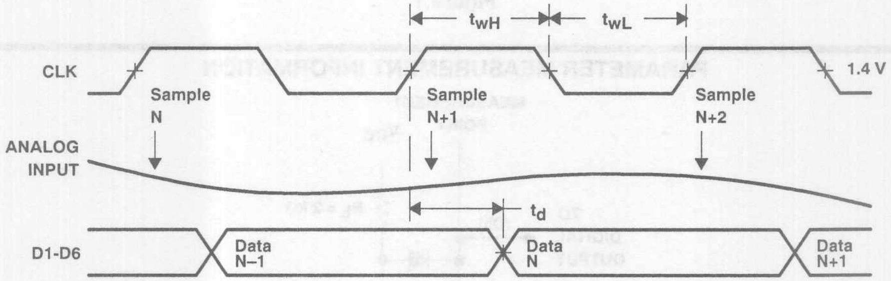
| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| $V_{OH}$ | High-level output voltage | $I_{OH} = -400\ \mu A$ | 2.4 | | | V |
| $V_{OL}$ | Low-level output voltage | $I_{OL} = 4$ mA | | | 0.4 | V |
| $I_I$ | Analog input current | $V_I = 0$ to 5 V, $f_{clock} = 10$ MHz | | ± 0.5 | | mA |
| $I_{IH}$ | Digitial high-level input current | $V_I = 5$ V | | | 1 | μA |
| $I_{IL}$ | Digital low-level input current | $V_I = 0$ | | | – 1 | μA |
| $I_{refB}$ | Reference current | $V_{refB} = 0$ V | | – 10 | – 20 | mA |
| $I_{refT}$ | Reference current | $V_{refT} = 5$ V | | 10 | 20 | mA |
| $C_i$ | Analog input capacitance | | | 50 | | pF |
| $I_{CC}$ | Supply current | $f_{clock} = 8$ MHz | | 30 | 60 | mA |

## operating characteristics over operating supply voltage range, $T_A$ = 25°C (unless otherwise noted)

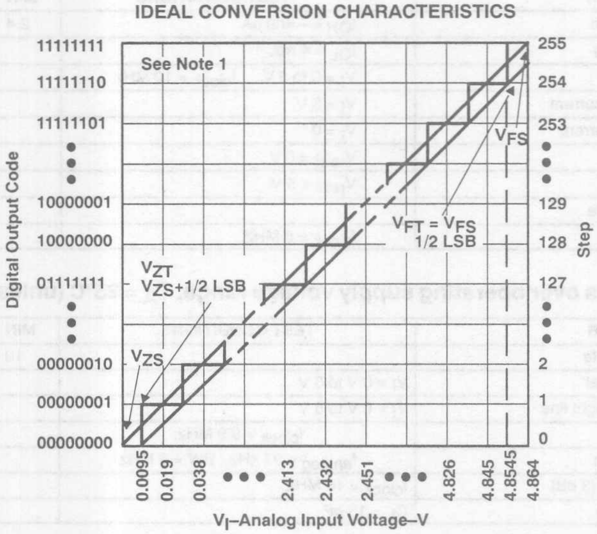
| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| $f_{max}$ | Maximum conversion rate | | 10 | 20 | | MHz |
| $E_D$ | Linearity error, differential | $V_I = 0$ V to 5 V | | ± 0.1 | ± 0.2 | %FSR |
| $E_L$ | Linearity error, best straight line | $V_I = 0$ V to 5 V | | | ±0.4 | %FSR |
| SNR† | Signal to noise ratio | $f_{clock} = 9.9$ MHz, $f_{analog} = 97$ kHz, BW = 5 MHz | | – 50 | | dB |
| THD | Total harmonic distortion | | | 51 | | dB |
| BW | Analog input bandwidth (3 dB) | $f_{clock} = 10$ MHz | | 5 | | MHz |
| $t_d$ | Digital output delay time | $C_L = 15$ pF | | 10 | 30 | ns |

† SNR is total noise without THD.

## timing diagram



## TYPICAL CHARACTERISTICS



NOTE 1: This curve is based on the assumption that $V_{refB}$ and $V_{refT}$ have been adjusted so that the voltage at the transition from digital 0 to 1 ($V_{ZT}$) is 0 and the transition to full scale ($V_{FT}$) is 4.8545 V. 1 LSB = 19 mV.

Figure 1

## PARAMETER MEASUREMENT INFORMATION

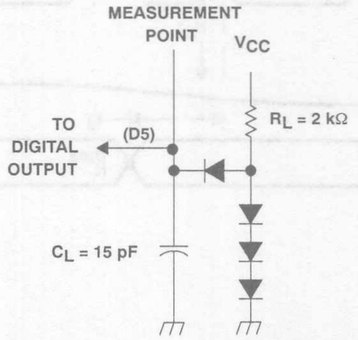


Figure 2. Load Circuit

## APPLICATIONS INFORMATION

The following design recommendations will benefit the TLC5502 user:

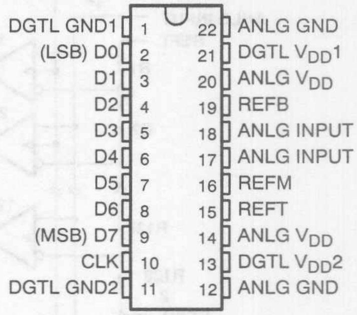
1. External analog and digital circuitry should be physically separated and shielded as much as possible to reduce system noise.
2. RF breadboarding or PCB techniques should be used throughout the evaluation and production process. Breadboards should be copper clad for bench evaluation.
3. Since the ANLG GND, DGTL GND1, and DGTL GND2 are not connected internally, these pins need to be connected externally. With breadboards, these ground lines should be connected through separate leads with proper supply bypassing. A good method is to use separate twisted-pair cables for the supply lines to minimize noise pickup. An analog and digital ground plane should be used on PCB layouts.
4. Since the ANLG $V_{DD}$, DGTL $V_{DD1}$, and DGTL $V_{DD2}$ are not connected internally, these pins also need to be connected externally. To connect ANLG $V_{DD}$, $DV_{DD1}$, and $DV_{DD2}$, a 50-Ω resistor should be placed in series with the DGTL $V_{DD1}$ pin and then a 0.1-µF capacitor to ground before being connected to the ANLG $V_{DD}$ and DGTL $DV_{DD2}$ supply.
5. ANLG $V_{DD}$ to ANLG GND, $DV_{DD1}$ to DGTL GND1, and $DV_{DD2}$ to DGTL GND2 should be decoupled with 1-µF and 0.01-µF capacitors, respectively, as close as possible to the appropriate device pins. A ceramic chip capacitor is recommended for the 0.01-µF capacitor. Care should be exercised to assure a solid noise free ground connection for the analog and digital grounds.
6. The no connection (NC) pins on the small-outline package should be connected to ground.
7. ANLG $V_{DD}$, ANLG GND, and the ANLG INPUT pins should be shielded from the higher-frequency pins, CLK and D0-D7. If possible, ANLG GND traces should be placed on both sides of the ANLG INPUT traces on the PCB.
8. In testing or application of the device, the resistance of the driving source connected to the analog input should be 10 Ω or less within the analog frequency range of interest.

# TLC5503-2
# 8-BIT ANALOG-TO-DIGITAL CONVERTER

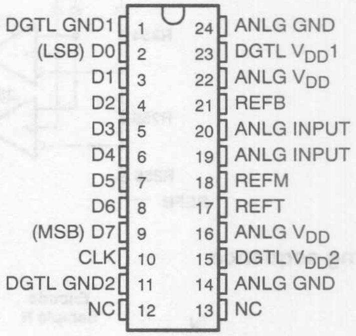
D3739, FEBRUARY 1991

- **LinEPIC™ 1-μm CMOS Process**
- **8-Bit Resolution**
- **Differential Linearity Error . . . ±0.4% Max**
- **Maximum Conversion Rate . . . 25 MHz Typ**
  **. . . 20 MHz Min**
- **Analog Input Voltage Range . . . 3 V to $V_{CC}$**
- **TTL Digital I/O Level**
- **Low Power Consumption . . . 190 mW Typ**
- **5-V Single-Supply Operation**

N PACKAGE
(TOP VIEW)



DW PACKAGE
(TOP VIEW)



NC – No internal connection

## description

The TLC5503-2 is a low-power ultra-high-speed video-band analog-to-digital converter manufactured using the LinEPIC™ CMOS process. It uses full-parallel comparison (flash method) for high-speed conversion of a wide-band analog signal (such as a video signal) to a digital signal at a sampling rate of dc to 25 MHz. Its high-speed capability makes the TLC5503-2 suitable for digital video applications such as digital TV, video processing with a computer, or radar signal processing.

Separate analog and digital supply pins are provided to reduce coupling between the high-speed digital switching sections and the lower-frequency analog signal comparators. This pin partitioning minimizes crosstalk and spurious signals. The two analog inputs (pins 17 and 18 on the N package; pins 19 and 20 on the DW package) should be connected together externally. The REFM input (pin 16 on the N package; pin 18 on the DW package) can be used to adjust for small tolerances in the resistor voltage divider by applying an external midpoint voltage.

The TLC5503-2 is characterized for operation from 0°C to 70°C.

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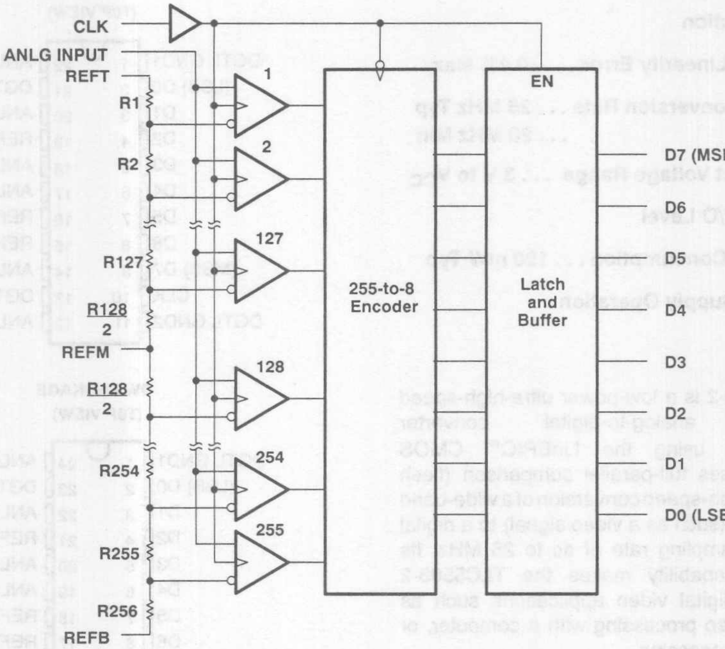
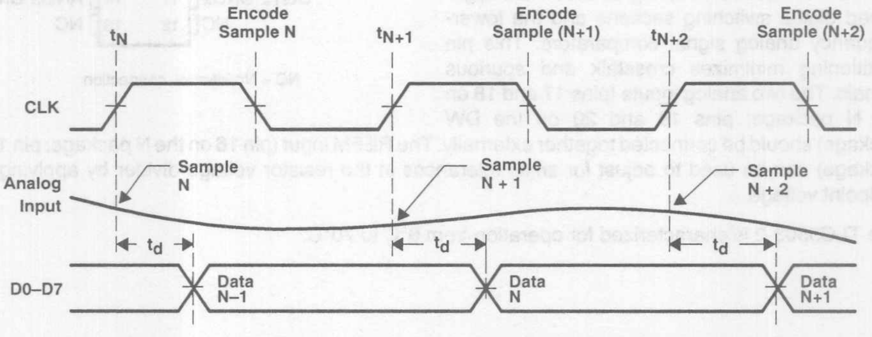
## functional block diagram

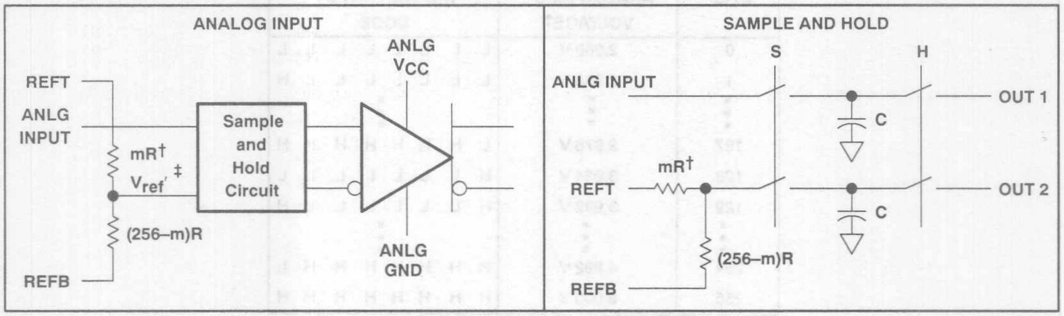


## operating sequence



Following the operating sequence above, the rising edge of the clock samples the analog input (sample N) at time $t_N$ and latches sample N – 1 at the output (with a delay $t_d$). Sample N is encoded to eight digital lines on the next falling edge of the clock and then the following high clock level latches these eight bits to the outputs (with a delay $t_d$) and acquires sample N + 1. Conversion is completed in one clock cycle and continues the sequence for the next cycle.

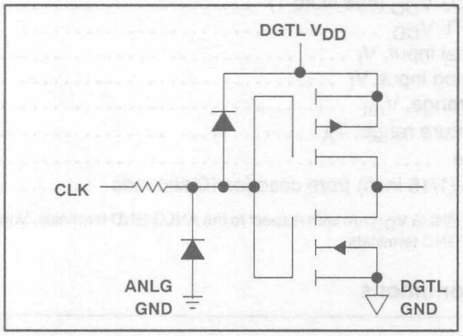
## equivalents of analog input circuit



† m = comparator position along the resistor string.

‡ $V_{ref}' = [V_{refT} - V_{refB}]\left[1 - \frac{m}{256}\right] + V_{refB}$

## equivalent of digital input circuit



FUNCTION TABLE

| STEP | ANALOG INPUT VOLTAGE† | DIGITAL OUTPUT CODE |
|---|---|---|
| 0 | 2.960 V | L L L L L L L L |
| 1 | 2.968 V | L L L L L L L H |
| ⋮ | ⋮ | ⋮ |
| 127 | 3.976 V | L H H H H H H H |
| 128 | 3.984 V | H L L L L L L L |
| 129 | 3.992 V | H L L L L L L H |
| ⋮ | ⋮ | ⋮ |
| 254 | 4.992 V | H H H H H H H L |
| 255 | 5.000 V | H H H H H H H H |

† These values are based on the assumption that $V_{refB}$ and $V_{refT}$ have been adjusted so that the voltage at the transition from digital 0 to 1 ($V_{ZT}$) is 2.964 V and the transition to full scale ($V_{FT}$) is 4.996 V. 1 LSB = 8 mV.

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage range, ANLG $V_{DD}$ (see Note 1) ........ – 0.5 V to 7 V
Supply voltage range, DGTL $V_{DD}$ ........ – 0.5 V to 7 V
Input voltage range at digital input, $V_I$ ........ – 0.5 V to 7 V
Input voltage range at analog input, $V_I$ ........ – 0.5 V to ANLG $V_{DD}$ + 0.5 V
Analog reference voltage range, $V_{ref}$ ........ – 0.5 V to ANLG $V_{DD}$ + 0.5 V
Operating free-air temperature range, $T_A$ ........ 0°C to 70°C
Storage temperature range ........ – 55°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds ........ 260°C

NOTE 1: Voltages at analog inputs and ANLG $V_{DD}$ are with respect to the ANLG GND terminals. Voltages at the digital outputs and DGTL $V_{DD}$ are with respect to the DGTL GND terminals.

### recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|
| Supply voltage, ANLG $V_{DD}$ | 4.75 | 5 | 5.25 | V |
| Supply voltage, DGTL $V_{DD}$ | 4.75 | 5 | 5.25 | V |
| High-level input voltage, $V_{IH}$ | 2 | | | V |
| Low-level input voltage, $V_{IL}$ | | | 0.8 | V |
| Input voltage at analog input, $V_I$ | 3 | | 5 | V |
| Analog reference voltage (top side), $V_{refT}$ | | ANLG $V_{DD}$ | | V |
| Analog reference voltage (bottom side), $V_{refB}$ | 2.5 | 3 | | V |
| Differential reference voltage, $V_{refT} - V_{refB}$ | | 2 | | V |
| High-level output current, $I_{OH}$ | | | – 400 | μA |
| Low-level output current, $I_{OL}$ | | | 4 | mA |
| Clock pulse duration, high-level or low-level, $t_{wH}$ or $t_{wL}$ | 25 | | | ns |
| Operating free-air temperature, $T_A$ | 0 | | 70 | °C |

### electrical characteristics over operating supply voltage range, $T_A$ = 25°C (unless otherwise noted)

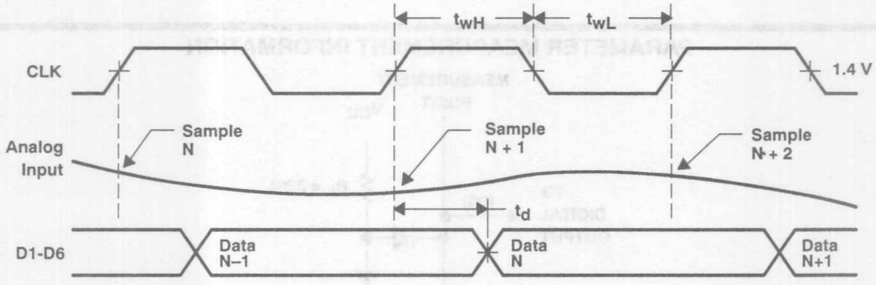
| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $V_{OH}$ | High-level output voltage | $I_{OH}$ = – 400 μA | | 2.4 | | | V |
| $V_{OL}$ | Low-level output voltage | $I_{OL}$ = 4 mA | | | | 0.4 | V |
| $I_I$ | Analog input current | $V_I$ = 3 to 5 V, | $f_{clock}$ = 15 MHz | | ± 0.3 | | mA |
| $I_{IH}$ | Digitial high-level input current | $V_I$ = 5 V | | | | 1 | μA |
| $I_{IL}$ | Digital low-level input current | $V_I$ = 0 | | | | – 1 | μA |
| $I_{refB}$ | Reference current | $V_{refB}$ = 3 V | | | – 12 | – 20 | mA |
| $I_{refT}$ | Reference current | $V_{refT}$ = 5 V | | | 12 | 20 | mA |
| $C_i$ | Analog input capacitance | | | | 50 | | pF |
| $I_{CC}$ | Supply current | $f_{clock}$ = 15 MHz | | | 37 | 60 | mA |

### operating characteristics over operating supply voltage range, $T_A$ = 25°C (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| $f_{max}$ | Maximum conversion rate | | 20 | 25 | | MHz |
| $E_D$ | Linearity error, differential | $V_I$ = 3 V to 5 V | | | ± 0.4 | %FSR |
| $E_L$ | Linearity error, best straight line | $V_I$ = 3 V to 5 V | | | ±0.4 | %FSR |
| $G_{diff}$ | Differential gain | NTSC 40-IRE modulated ramp, | | 0.9% | | |
| $\phi_{diff}$ | Differential phase | $f_{clock}$ = 14.4 MHz | | 0.6° | | |
| SNR[†] | Signal to noise ratio | $f_{clock}$ = 16.4 MHz, $f_{analog}$ = 1.248 MHz (90% P-P), | | 48 | | dB |
| THD | Total harmonic distortion | BW = 8.2 MHz | | – 50 | | dB |
| $t_d$ | Digital output dalay time | $C_L$ = 15 pF | | 10 | 30 | ns |

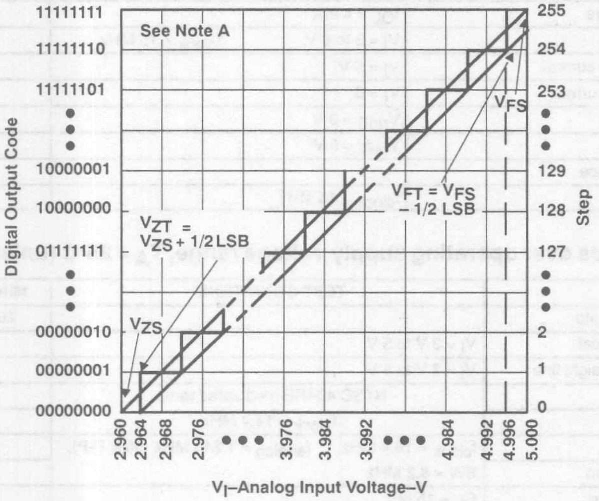
[†] SNR does not include THD.

### timing diagram



## TYPICAL CHARACTERISTICS

### IDEAL CONVERSION CHARACTERISTICS



NOTE A: This curve is based on the assumption that $V_{refB}$ and $V_{refT}$ have been adjusted so that the voltage at the transition from digital 0 to 1 ($V_{ZT}$) is 2.964 V and the transition to full scale ($V_{FT}$) is 4.996 V. 1 LSB = 8 mV.

Figure 1

## PARAMETER MEASUREMENT INFORMATION

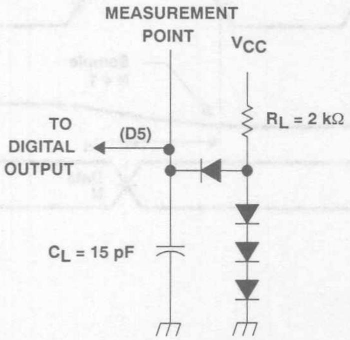


Figure 2. Load Circuit

## APPLICATION INFORMATION

The following design recommendations will benefit the TLC5503 user:

1. External analog and digital circuitry should be physically separated and shielded as much as possible to reduce system noise.
2. RF breadboarding or PCB techniques should be used throughout the evaluation and production process. Breadboards should be copper clad for bench evaluation.
3. Since the ANLG GND, DGTL GND1, and DGTL GND2 are not connected internally, these pins need to be connected externally. With breadboards, these ground lines should be connected through separate leads with proper supply bypassing. A good method is to use separate twisted-pair cables for the supply lines to minimize noise pickup. An analog and digital ground plane should be used on PCB layouts.
4. Since the ANLG $V_{DD}$, DGTL $V_{DD}1$, and DGTL $V_{DD}2$, are not connected internally, these pins also need to be connected externally. To connection ANLG $V_{DD}$ to $DV_{DD}1$ or $DV_{DD}2$, a 50-Ω resistor should be placed in series with the DGTL $V_{DD}1$ pin and then a 0.1-μF capacitor to ground before being connected to the ANLG $V_{DD}$, and DGTL $DV_{DD}2$ supply.
5. ANLG $V_{DD}$ to ANLG GND, $DV_{DD}1$ to DGTL GND1, and $DV_{DD}2$ to DGTL GND2 should be decoupled with 1-μF and 0.01-μF capacitors, respectively, as close as possible to the appropriate device pins. A ceramic chip capacitor is recommended for the 0.01-μF capacitor. Care should be exercised to assure a solid noise-free ground connection for the analog and digital grounds.
6. The no connection (NC) pins on the small-outline package should be connected to ground.
7. ANLG $V_{DD}$, ANLG GND, and the ANLG INPUT pins should be shielded from the higher-frequency pins, CLK and D0-D7. If possible, ANLG GND traces should be placed on both sides of the ANLG INPUT traces on the PCB.
8. In testing or application of the device, the resistance of the driving source connected to the analog input should be 10 Ω or less within the analog frequency range of interest.

# TLE2021, TLE2021A, TLE2021B
# EXCALIBUR HIGH-SPEED LOW-POWER PRECISION OPERATIONAL AMPLIFIERS

D3197, FEBRUARY 1989 – REVISED FEBRUARY 1991

## available features

- **Supply Current . . . 230 µA Max**
- **High Unity-Gain Bandwidth . . . 2 MHz Typ**
- **High Slew Rate . . . 0.45 V/µs Min**
- **Supply Current Change Over Military Temp Range . . . 10 µA Typ**
- **Specified for Both 5-V Single-Supply and ± 15 V Operation**
- **Phase-Reversal Protection**
- **High Open-Loop Gain . . . 6.5 V/µV (136 dB) Typ**
- **Low Offset Voltage . . . 100 µV Max**
- **Offset Voltage Drift With Time . . . 0.005 µV/mo Typ**
- **Low Input Bias current . . . 50 nA Max**
- **Low Noise Voltage . . . 19 nV/$\sqrt{Hz}$ typ**

## description

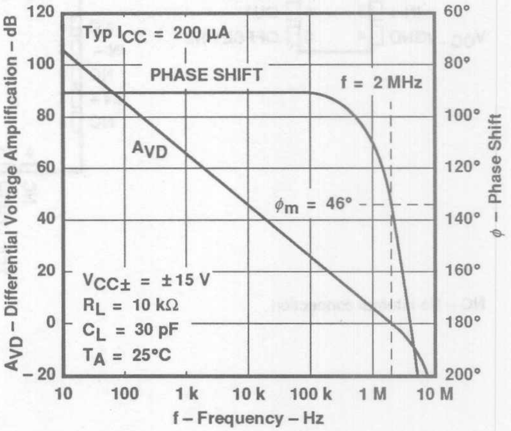
The TLE2021, TLE2021A, and TLE2021B devices are precision, high-speed, low-power operational amplifiers using a new Texas Instruments patent-pending Excalibur process. These devices combine the best features of the OP21 with highly improved slew rate and unity-gain bandwidth.

The complementary bipolar Excalibur process utilizes isolated vertical P-N-P transistors that yield dramatic improvement in unity-gain bandwidth and slew rate over similar devices.

The addition of a patent-pending bias circuit in conjunction with this process results in extremely stable parameters with both time and temperature. This means that a "precision" device remains a precision device even with changes in temperature and over years of use.

This combination of excellent dc performance with a common-mode input voltage range that

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT
vs
FREQUENCY



**AVAILABLE OPTIONS**

| $T_A$ | $V_{IO}$ max AT 25°C | PACKAGE SMALL-OUTLINE (D) | CHIP CARRIER (FK) | CERAMIC DIP (JG) | METAL CAN (L) | PLASTIC DIP (P) |
|---|---|---|---|---|---|---|
| 0°C to 70°C | 200 µV | TLE2021ACD | — | — | — | TLE2021ACP |
| | 500 µV | TLE2021CD | — | — | TLE2021CL | TLE2021CP |
| – 40°C to 85°C | 200 µV | TLE2021AID | — | — | TLE2021AIL | TLE2021AIP |
| | 500 µV | TLE2021ID | — | — | TLE2021IL | TLE2021IP |
| – 55°C to 125°C | 100 µV | — | — | TLE2021BMJG | TLE2021BML | — |
| | 200 µV | TLE2021AMD | TLE2021AMFK | TLE2021AMJG | TLE2021AML | TLE2021AMP |
| | 500 µV | TLE2021MD | TLE2021MFK | TLE2021MJG | TLE2021ML | TLE2021MP |

D packages are available taped and reeled. Add "R" suffix to device type, (e.g.,TLE2021ACDR).

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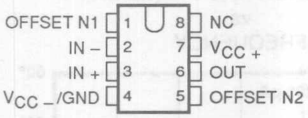
## description (continued)

includes the negative rail makes these devices the ideal choice for low-level signal conditioning applications in either single supply or split-supply configurations. In addition, these devices offer phase-reversal protection circuitry that eliminates an unexpected change in output states when one of the inputs goes below the negative supply rail.

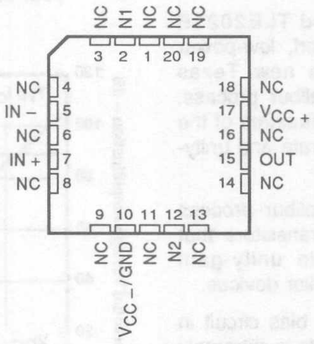
A variety of available options includes small-outline and chip carrier versions for high-density systems applications.

The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from –40°C to 85°C. The M-suffix devices are characterized for operation over the full military temperature range of –55°C to 125°C.

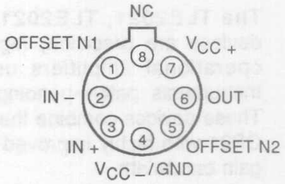
**D, JG, or P PACKAGE**
**(TOP VIEW)**



**FK PACKAGE**
**(TOP VIEW)**



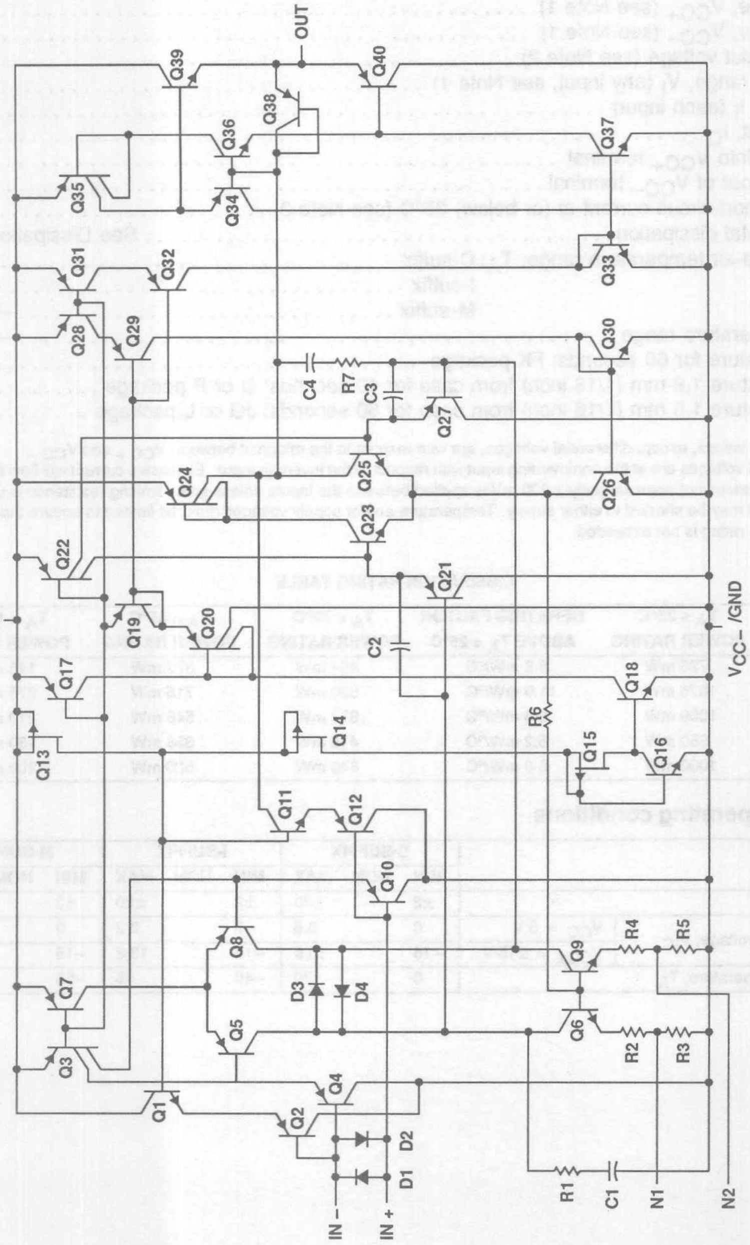
**L PACKAGE**
**(TOP VIEW)**



Pin 4 of the L package is in electrical contact with the case.

NC – No internal connection

**equivalent schematic (each amplifier)**



## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|---|
| Supply voltage, $V_{CC+}$ (see Note 1) | 20 V |
| Supply voltage, $V_{CC-}$ (see Note 1) | −20 V |
| Differential input voltage (see Note 2) | ±0.6V |
| Input voltage range, $V_I$ (any input, see Note 1) | $\pm V_{CC}$ |
| Input current, $I_I$ (each input) | ±1 mA |
| Output current, $I_O$ | ±20 mA |
| Total current into $V_{CC+}$ terminal | 20 mA |
| Total current out of $V_{CC-}$ terminal | 20 mA |
| Duration of short-circuit current at (or below) 25°C (see Note 3) | unlimited |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range, $T_A$: C-suffix | 0°C to 70°C |
| I-suffix | −40°C to 85°C |
| M-suffix | −55°C to 125°C |
| Storage temperature range | −65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG or L package | 300°C |

NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between $V_{CC+}$ and $V_{CC-}$.

2. Differential voltages are at the noninverting input with respect to the inverting input. Excessive current will flow if a differential input voltage in excess of approximately ± 600 mV is applied between the inputs unless some limiting resistance is used.

3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \le 25°C$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25°C$ | $T_A = 70°C$ POWER RATING | $T_A = 85°C$ POWER RATING | $T_A = 125°C$ POWER RATING |
|---|---|---|---|---|---|
| D | 725 mW | 5.8 mW/°C | 464 mW | 377 mW | 145 mW |
| FK | 1375 mW | 11.0 mW/°C | 880 mW | 715 mW | 275 mW |
| JG | 1050 mW | 8.4 mW/°C | 672 mW | 546 mW | 210 mW |
| L | 650 mW | 5.2 mW/°C | 416 mW | 338 mW | 130 mW |
| P | 1000 mW | 8.0 mW/°C | 640 mW | 520 mW | 200 mW |

## recommended operating conditions

| | | C-SUFFIX | | | I-SUFFIX | | | M-SUFFIX | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MIN | NOM | MAX | MIN | NOM | MAX | MIN | NOM | MAX | |
| Supply voltage, $V_{CC}$ | | ±2 | | ±20 | ±2 | | ±20 | ±2 | | ±20 | V |
| Common-mode input voltage, $V_{IC}$ | $V_{CC} = 5$ V | 0 | | 3.5 | 0 | | 3.2 | 0 | | 3.2 | V |
| | $V_{CC\pm} = \pm 15$ V | −15 | | 13.5 | −15 | | 13.2 | −15 | | 13.2 | |
| Operating free-air temperature, $T_A$ | | 0 | | 70 | −40 | | 85 | −55 | | 125 | °C |

## electrical characteristics at specified free-air temperature, $V_{CC}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2021 | | | TLE2021A | | | TLE2021B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC}$ = 0, $R_S$ = 50 Ω | 25°C | | 120 | 600 | | 100 | 300 | | 80 | 200 | µV |
| | | | Full range | | | 850 | | | 600 | | | 300 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 2 | | | 2 | | | 2 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.005 | | | 0.005 | | | 0.005 | | µV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 0.2 | 3 | | 0.2 | 3 | | 0.2 | 3 | nA |
| | | | Full range | | | 3 | | | 3 | | | 3 | |
| $I_{IB}$ | Input bias current | | 25°C | | 25 | 50 | | 25 | 50 | | 25 | 50 | nA |
| | | | Full range | | | 50 | | | 50 | | | 50 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S$ = 50 Ω | 25°C | 0 to 3.5 | – 0.3 to 4 | | 0 to 3.5 | – 0.3 to 4 | | 0 to 3.5 | – 0.3 to 4 | | V |
| | | | Full range | 0 to 3.5 | | | 0 to 3.5 | | | 0 to 3.5 | | | |
| $V_{OH}$ | High-level output voltage | $R_L$ = 10 kΩ | 25°C | 4 | 4.3 | | 4 | 4.3 | | 4 | 4.3 | | V |
| | | | Full range | 3.9 | | | 3.9 | | | 3.9 | | | |
| $V_{OL}$ | Low-level output voltage | | 25°C | | 0.7 | 0.8 | | 0.7 | 0.8 | | 0.7 | 0.8 | V |
| | | | Full range | | | 0.85 | | | 0.85 | | | 0.85 | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O$ = 1.4 V to 4 V, $R_L$ = 10 kΩ | 25°C | 0.3 | 1.5 | | 0.3 | 1.5 | | 0.3 | 1.5 | | V/µV |
| | | | Full range | 0.3 | | | 0.3 | | | 0.3 | | | |
| CMRR | Common-mode rejection ratio | $V_{IC}$ = $V_{ICR}$ min, $R_S$ = 50 Ω | 25°C | 85 | 110 | | 85 | 110 | | 85 | 110 | | dB |
| | | | Full range | 80 | | | 80 | | | 80 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC} / \Delta V_{IO}$) | $V_{CC}$ = 5 V to 30 V | 25°C | 105 | 120 | | 105 | 120 | | 105 | 120 | | dB |
| | | | Full range | 100 | | | 100 | | | 100 | | | |
| $I_{CC}$ | Supply current | $V_O$ = 2.5 V, No load | 25°C | | 170 | 230 | | 170 | 230 | | 170 | 230 | µA |
| | | | Full range | | | 230 | | | 230 | | | 230 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | Full range | | 5 | | | 5 | | | 5 | | µA |

†Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A$ = 150°C extrapolated to $T_A$ = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2021 | | | TLE2021A | | | TLE2021B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 120 | 500 | | 80 | 200 | | 40 | 100 | µV |
| | | | Full range | | | 750 | | | 500 | | | 200 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 2 | | | 2 | | | 2 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.006 | | | 0.006 | | | 0.006 | | µV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 0.2 | 3 | | 0.2 | 3 | | 0.2 | 3 | nA |
| | | | Full range | | | 3 | | | 3 | | | 3 | |
| $I_{IB}$ | Input bias current | | 25°C | | 25 | 50 | | 25 | 50 | | 25 | 50 | nA |
| | | | Full range | | | 50 | | | 50 | | | 50 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | 25°C | − 15<br>to<br>13.5 | − 15.3<br>to<br>14 | | − 15<br>to<br>13.5 | − 15.3<br>to<br>14 | | − 15<br>to<br>13.5 | − 15.3<br>to<br>14 | | V |
| | | | Full range | − 15<br>to<br>13.5 | | | − 15<br>to<br>13.5 | | | − 15<br>to<br>13.5 | | | |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $R_L = 10\ k\Omega$ | 25°C | 14 | 14.3 | | 14 | 14.3 | | 14 | 14.3 | | V |
| | | | Full range | 13.9 | | | 13.9 | | | 13.9 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | 25°C | − 13.7 | − 14.1 | | − 13.7 | − 14.1 | | − 13.7 | − 14.1 | | V |
| | | | Full range | − 13.7 | | | − 13.7 | | | − 13.7 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = \pm 10$ V, $R_L = 10\ k\Omega$ | 25°C | 1 | 6.5 | | 1 | 6.5 | | 1 | 6.5 | | V/µV |
| | | | Full range | 1 | | | 1 | | | 1 | | | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 25°C | 100 | 115 | | 100 | 115 | | 100 | 115 | | dB |
| | | | Full range | 96 | | | 96 | | | 96 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 2.5$ V to $\pm 15$ V | 25°C | 105 | 120 | | 105 | 120 | | 105 | 120 | | dB |
| | | | Full range | 100 | | | 100 | | | 100 | | | |
| $I_{CC}$ | Supply current | $V_O = 0$, No load | 25°C | | 200 | 300 | | 200 | 300 | | 200 | 300 | µA |
| | | | Full range | | | 300 | | | 300 | | | 300 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | Full range | | 6 | | | 6 | | | 6 | | µA |

†Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## electrical characteristics at specified free-air temperature, $V_{CC} = 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2021 | | | TLE2021A | | | TLE2021B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 120 | 600 | | 100 | 300 | | 80 | 200 | µV |
| | | | Full range | | | 950 | | | 600 | | | 300 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 2 | | | 2 | | | 2 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.005 | | | 0.005 | | | 0.005 | | µV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 0.2 | 3 | | 0.2 | 3 | | 0.2 | 3 | nA |
| | | | Full range | | | 4 | | | 4 | | | 4 | |
| $I_{IB}$ | Input bias current | | 25°C | | 25 | 50 | | 25 | 50 | | 25 | 50 | nA |
| | | | Full range | | | 50 | | | 50 | | | 50 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | 25°C | 0<br>to<br>3.5 | – 0.3<br>to<br>4 | | 0<br>to<br>3.5 | – 0.3<br>to<br>4 | | 0<br>to<br>3.5 | – 0.3<br>to<br>4 | | V |
| | | | Full range | 0<br>to<br>3.2 | | | 0<br>to<br>3.2 | | | 0<br>to<br>3.2 | | | |
| $V_{OH}$ | High-level output voltage | $R_L = 10\ k\Omega$ | 25°C | 4 | 4.3 | | 4 | 4.3 | | 4 | 4.3 | | V |
| | | | Full range | 3.9 | | | 3.9 | | | 3.9 | | | |
| $V_{OL}$ | Low-level output voltage | | 25°C | | 0.7 | 0.8 | | 0.7 | 0.8 | | 0.7 | 0.8 | V |
| | | | Full range | | | 0.9 | | | 0.9 | | | 0.9 | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = 1.4$ V to 4 V, $R_L = 10\ k\Omega$ | 25°C | 0.3 | 1.5 | | 0.3 | 1.5 | | 0.3 | 1.5 | | V/µV |
| | | | Full range | 0.25 | | | 0.25 | | | 0.25 | | | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 25°C | 85 | 110 | | 85 | 110 | | 85 | 110 | | dB |
| | | | Full range | 80 | | | 80 | | | 80 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC} / \Delta V_{IO}$) | $V_{CC} = 5$ V to 30 V | 25°C | 105 | 120 | | 105 | 120 | | 105 | 120 | | dB |
| | | | Full range | 100 | | | 100 | | | 100 | | | |
| $I_{CC}$ | Supply current | $V_O = 2.5$ V, No load | 25°C | | 170 | 230 | | 170 | 230 | | 170 | 230 | µA |
| | | | Full range | | | 230 | | | 230 | | | 230 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | Full range | | 6 | | | 6 | | | 6 | | µA |

†Full range is – 40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TLE2021 | | | TLE2021A | | | TLE2021B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC} = 0$, | $R_S = 50\ \Omega$ | 25°C | | 120 | 500 | | 80 | 200 | | 40 | 100 | μV |
| | | | | Full range | | | 850 | | | 500 | | | 200 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 2 | | | 2 | | | 2 | | μV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.006 | | | 0.006 | | | 0.006 | | μV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 0.2 | 3 | | 0.2 | 3 | | 0.2 | 3 | nA |
| | | | | Full range | | | 4 | | | 4 | | | 4 | |
| $I_{IB}$ | Input bias current | | | 25°C | | 25 | 50 | | 25 | 50 | | 25 | 50 | nA |
| | | | | Full range | | | 50 | | | 50 | | | 50 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | | 25°C | − 15<br>to<br>13.5 | − 15.3<br>to<br>14 | | − 15<br>to<br>13.5 | − 15.3<br>to<br>14 | | − 15<br>to<br>13.5 | − 15.3<br>to<br>14 | | V |
| | | | | Full range | − 15<br>to<br>13.2 | | | − 15<br>to<br>13.2 | | | − 15<br>to<br>13.2 | | | |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $R_L = 10\ k\Omega$ | | 25°C | 14 | 14.3 | | 14 | 14.3 | | 14 | 14.3 | | V |
| | | | | Full range | 13.9 | | | 13.9 | | | 13.9 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | | 25°C | − 13.7 | − 14.1 | | − 13.7 | − 14.1 | | − 13.7 | − 14.1 | | V |
| | | | | Full range | − 13.6 | | | − 13.6 | | | − 13.6 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = \pm 10$ V, | $R_L = 10\ k\Omega$ | 25°C | 1 | 6.5 | | 1 | 6.5 | | 1 | 6.5 | | V/μV |
| | | | | Full range | 0.75 | | | 0.75 | | | 0.75 | | | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min, | $R_S = 50\ \Omega$ | 25°C | 100 | 115 | | 100 | 115 | | 100 | 115 | | dB |
| | | | | Full range | 96 | | | 96 | | | 96 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 2.5$ V to ± 15 V | | 25°C | 105 | 120 | | 105 | 120 | | 105 | 120 | | dB |
| | | | | Full range | 100 | | | 100 | | | 100 | | | |
| $I_{CC}$ | Supply current | $V_O = 0$, | No load | 25°C | | 200 | 300 | | 200 | 300 | | 200 | 300 | μA |
| | | | | Full range | | | 300 | | | 300 | | | 300 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | | Full range | | 7 | | | 7 | | | 7 | | μA |

†Full range is − 40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## electrical characteristics at specified free-air temperature, $V_{CC}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TLE2021 | | | TLE2021A | | | TLE2021B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC}$ = 0, | $R_S$ = 50 Ω | 25°C | | 120 | 600 | | 100 | 300 | | 80 | 200 | µV |
| | | | | Full range | | | 1100 | | | 600 | | | 300 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 2 | | | 2 | | | 2 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.005 | | | 0.005 | | | 0.005 | | µV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 0.2 | 3 | | 0.2 | 3 | | 0.2 | 3 | nA |
| | | | | Full range | | | 5 | | | 5 | | | 5 | |
| $I_{IB}$ | Input bias current | | | 25°C | | 25 | 50 | | 25 | 50 | | 25 | 50 | nA |
| | | | | Full range | | | 50 | | | 50 | | | 50 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S$ = 50 Ω | | 25°C | 0<br>to<br>3.5 | −0.3<br>to<br>4 | | 0<br>to<br>3.5 | −0.3<br>to<br>4 | | 0<br>to<br>3.5 | −0.3<br>to<br>4 | | V |
| | | | | Full range | 0<br>to<br>3.2 | | | 0<br>to<br>3.2 | | | 0<br>to<br>3.2 | | | |
| $V_{OH}$ | High-level output voltage | $R_L$ = 10 kΩ | | 25°C | 4 | 4.3 | | 4 | 4.3 | | 4 | 4.3 | | V |
| | | | | Full range | 3.8 | | | 3.8 | | | 3.8 | | | |
| $V_{OL}$ | Low-level output voltage | | | 25°C | | 0.7 | 0.8 | | 0.7 | 0.8 | | 0.7 | 0.8 | V |
| | | | | Full range | | | 0.95 | | | 0.95 | | | 0.95 | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O$ = 1.4 V to 4 V, | $R_L$ = 10 kΩ | 25°C | 0.3 | 1.5 | | 0.3 | 1.5 | | 0.3 | 1.5 | | V/µV |
| | | | | Full range | 0.1 | | | 0.1 | | | 0.1 | | | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min, | $R_S$ = 50 Ω | 25°C | 85 | 110 | | 85 | 110 | | 85 | 110 | | dB |
| | | | | Full range | 80 | | | 80 | | | 80 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC} / \Delta V_{IO}$) | $V_{CC}$ = 5 V to 30 V | | 25°C | 105 | 120 | | 105 | 120 | | 105 | 120 | | dB |
| | | | | Full range | 100 | | | 100 | | | 100 | | | |
| $I_{CC}$ | Supply current | $V_O$ = 2.5 V, | No load | 25°C | | 170 | 230 | | 170 | 230 | | 170 | 230 | µA |
| | | | | Full range | | | 230 | | | 230 | | | 230 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | | Full range | | 9 | | | 9 | | | 9 | | µA |

†Full range is – 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A$ = 150°C extrapolated to $T_A$ = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2021 | | | TLE2021A | | | TLE2021B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 120 | 500 | | 80 | 200 | | 40 | 100 | μV |
| | | | Full range | | | 1000 | | | 500 | | | 200 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 2 | | | 2 | | | 2 | | μV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.006 | | | 0.006 | | | 0.006 | | μV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 0.2 | 3 | | 0.2 | 3 | | 0.2 | 3 | nA |
| | | | Full range | | | 5 | | | 5 | | | 5 | |
| $I_{IB}$ | Input bias current | | 25°C | | 25 | 50 | | 25 | 50 | | 25 | 50 | nA |
| | | | Full range | | | 50 | | | 50 | | | 50 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | 25°C | − 15<br>to<br>13.5 | − 15.3<br>to<br>14 | | − 15<br>to<br>13.5 | − 15.3<br>to<br>14 | | − 15<br>to<br>13.5 | − 15.3<br>to<br>14 | | V |
| | | | Full range | − 15<br>to<br>13.2 | | | − 15<br>to<br>13.2 | | | − 15<br>to<br>13.2 | | | |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $R_L = 10\ k\Omega$ | 25°C | 14 | 14.3 | | 14 | 14.3 | | 14 | 14.3 | | V |
| | | | Full range | 13.8 | | | 13.8 | | | 13.8 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | 25°C | − 13.7 | − 14.1 | | − 13.7 | − 14.1 | | − 13.7 | − 14.1 | | V |
| | | | Full range | − 13.6 | | | − 13.6 | | | − 13.6 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = \pm 10$ V, $R_L = 10\ k\Omega$ | 25°C | 1 | 6.5 | | 1 | 6.5 | | 1 | 6.5 | | V/μV |
| | | | Full range | 0.5 | | | 0.5 | | | 0.5 | | | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 25°C | 100 | 115 | | 100 | 115 | | 100 | 115 | | dB |
| | | | Full range | 96 | | | 96 | | | 96 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 2.5$ V to ± 15 V | 25°C | 105 | 120 | | 105 | 120 | | 105 | 120 | | dB |
| | | | Full range | 100 | | | 100 | | | 100 | | | |
| $I_{CC}$ | Supply current | $V_O = 0$, No load | 25°C | | 200 | 300 | | 200 | 300 | | 200 | 300 | μA |
| | | | Full range | | | 300 | | | 300 | | | 300 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | Full range | | 10 | | | 10 | | | 10 | | μA |

†Full range is − 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC}$ = 5 V (unless otherwise noted)

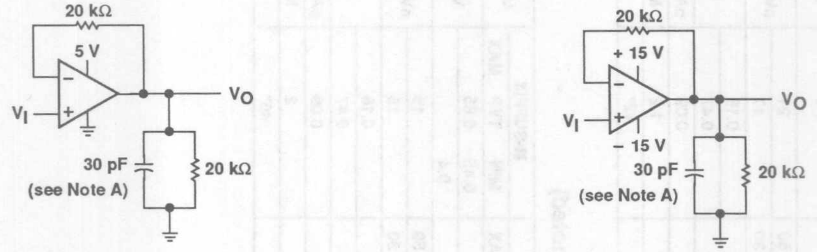
| PARAMETER | | TEST CONDITIONS | $T_A$ | C-SUFFIX | | | I-SUFFIX | | | M-SUFFIX | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O$ = 1 V to 3 V, See Figure 1 | 25°C | | 0.5 | | | 0.5 | | | 0.5 | | V/μs |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz | 25°C | | 21 | 50 | | 21 | 50 | | 21 | | $\mathrm{nV}/\sqrt{\mathrm{Hz}}$ |
| | | f = 1 kHz | 25°C | | 17 | 30 | | 17 | 30 | | 17 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.16 | | | 0.16 | | | 0.16 | | μV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.47 | | | 0.47 | | | 0.47 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.09 | | | 0.09 | | | 0.09 | | $\mathrm{pA}/\sqrt{\mathrm{Hz}}$ |
| $B_1$ | Unity-gain bandwidth | See Figure 3 | 25°C | | 1.2 | | | 1.2 | | | 1.2 | | MHz |
| $\phi_m$ | Phase margin at unity gain | See Figure 3 | 25°C | | 42° | | | 42° | | | 42° | | |

## operating characteristics at specified free-air temperature, $V_{CC\pm}$ = ± 15 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | C-SUFFIX | | | I-SUFFIX | | | M-SUFFIX | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O$ = ± 10 V, See Figure 1 | 25°C | 0.45 | 0.65 | | 0.45 | 0.65 | | 0.45 | 0.65 | | V/μs |
| | | | Full range | 0.45 | | | 0.42 | | | 0.4 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz | 25°C | | 19 | 50 | | 19 | 50 | | 19 | | $\mathrm{nV}/\sqrt{\mathrm{Hz}}$ |
| | | f = 1 kHz | 25°C | | 15 | 30 | | 15 | 30 | | 15 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.16 | | | 0.16 | | | 0.16 | | μV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.47 | | | 0.47 | | | 0.47 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.09 | | | 0.09 | | | 0.09 | | $\mathrm{pA}/\sqrt{\mathrm{Hz}}$ |
| $B_1$ | Unity-gain bandwidth | See Figure 3 | 25°C | | 2 | | | 2 | | | 2 | | MHz |
| $\phi_m$ | Phase margin at unity gain | See Figure 3 | 25°C | | 46° | | | 46° | | | 46° | | |

† Full range is 0°C to 70°C for the C-suffix devices, −40°C to 85°C for the I-suffix devices, and −55°C to 125°C for the M-suffix devices.

## PARAMETER MEASUREMENT INFORMATION

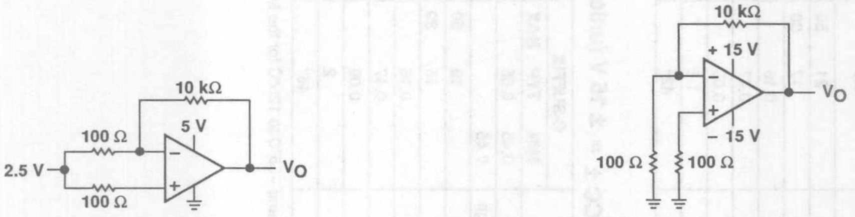


NOTE A: $C_L$ includes fixture capacitance.

(a) SINGLE-SUPPLY

(b) SPLIT-SUPPLY

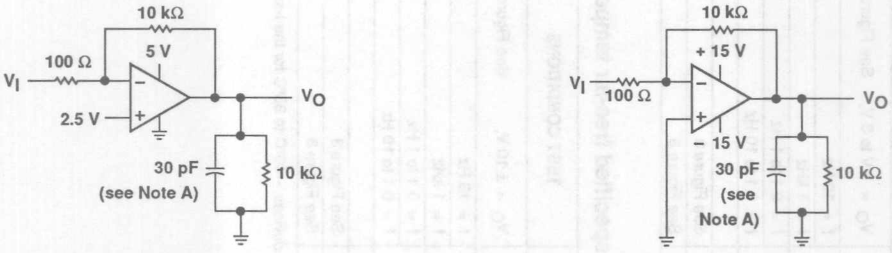
Figure 1. Slew Rate Test Circuit



(a) SINGLE-SUPPLY

(b) SPLIT-SUPPLY

Figure 2. Noise Voltage Test Circuit



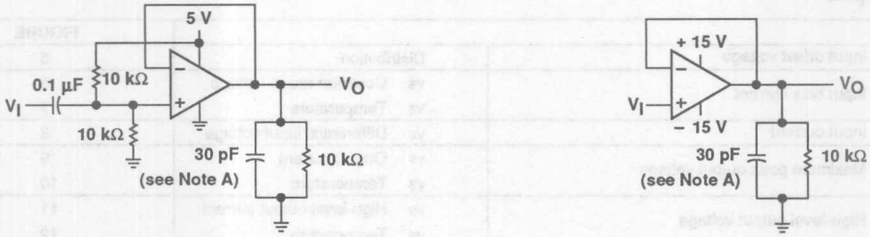
NOTE A: $C_L$ includes fixture capacitance.

(a) SINGLE-SUPPLY

(b) SPLIT-SUPPLY

Figure 3. Unity-Gain Bandwidth and Phase Margin Test Circuit

## PARAMETER MEASUREMENT INFORMATION



NOTE A: $C_L$ includes fixture capacitance.

(a) SINGLE-SUPPLY

(b) SPLIT-SUPPLY

**Figure 4. Small-Signal Pulse Response Test Circuit**

### typical values

Typical values as presented in this data sheet represent the median (50% point) of device parametric performance of initial devices from three wafer lots used for characterization.

## TYPICAL CHARACTERISTICS

### table of graphs

| | | | FIGURE |
|---|---|---|---|
| $V_{IO}$ | Input offset voltage | Distribution | 5 |
| $I_{IB}$ | Input bias current | vs Common-mode voltage | 6 |
| | | vs Temperature | 7 |
| $I_I$ | Input current | vs Differential input voltage | 8 |
| $V_{OM}$ | Maximum peak output voltage | vs Output current | 9 |
| | | vs Temperature | 10 |
| $V_{OH}$ | High-level output voltage | vs High-level output current | 11 |
| | | vs Temperature | 12 |
| $V_{OL}$ | Low-level output voltage | vs Low-level output current | 13 |
| | | vs Temperature | 14 |
| $V_{OPP}$ | Maximum peak-to-peak output voltage swing | vs Frequency | 15, 16 |
| $A_{VD}$ | Differential voltage amplification | vs Frequency | 17 |
| | | vs Temperature | 18 |
| $I_{OS}$ | Short-circuit output current | vs Supply voltage | 19, 20 |
| | | vs Temperature | 21, 22 |
| $I_{CC}$ | Supply current | vs Supply voltage | 23 |
| | | vs Temperature | 24 |
| CMRR | Common-mode rejection ratio | vs Frequency | 25 |
| SR | Slew rate | vs Temperature | 26 |
| | Pulse response | Small-signal | 27, 28 |
| | | Large-signal | 29, 30 |
| $V_{NPP}$ | Peak-to-peak equivalent input noise voltage | 0.1 to 1 Hz | 31 |
| | | 0.1 to 10 Hz | 32 |
| $V_n$ | Equivalent input noise voltage | vs Frequency | 33 |
| $B_1$ | Unity-gain bandwidth | vs Supply voltage | 34 |
| | | vs Temperature | 35 |
| $\phi_m$ | Phase margin | vs Supply voltage | 36 |
| | | vs Temperature | 37 |
| | | vs Capacitive load | 38 |
| | Phase shift | vs Frequency | 17 |

## TYPICAL CHARACTERISTICS[†]

DISTRIBUTION OF TLE2021
INPUT OFFSET VOLTAGE

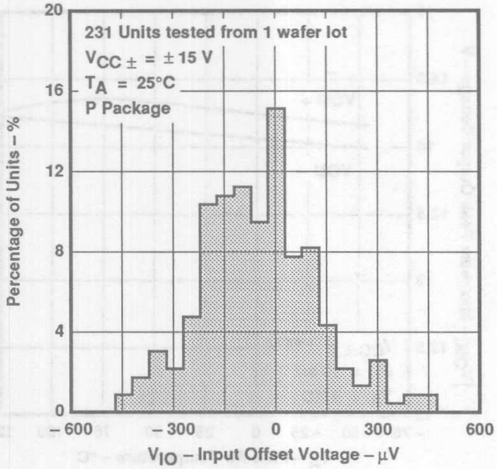


Figure 5

INPUT BIAS CURRENT
vs
COMMON-MODE INPUT VOLTAGE

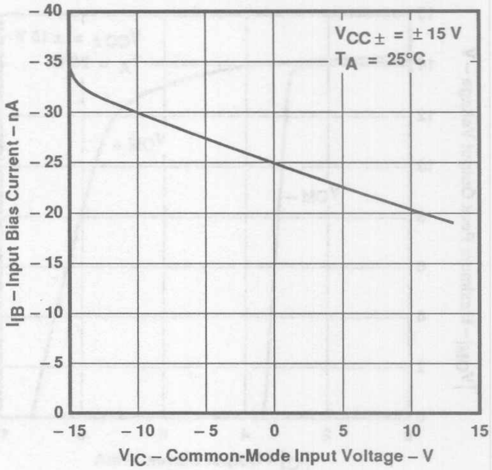


Figure 6

INPUT BIAS CURRENT
vs
FREE-AIR TEMPERATURE

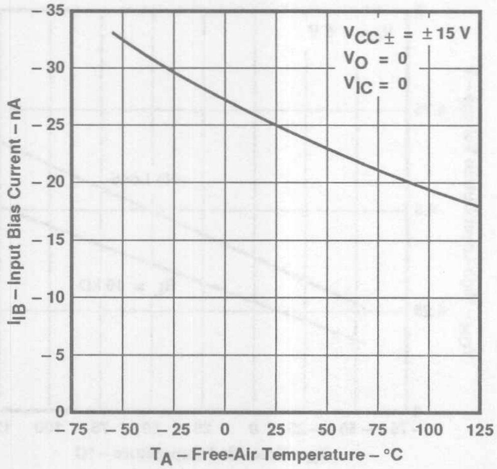


Figure 7

INPUT CURRENT
vs
DIFFERENTIAL INPUT VOLTAGE

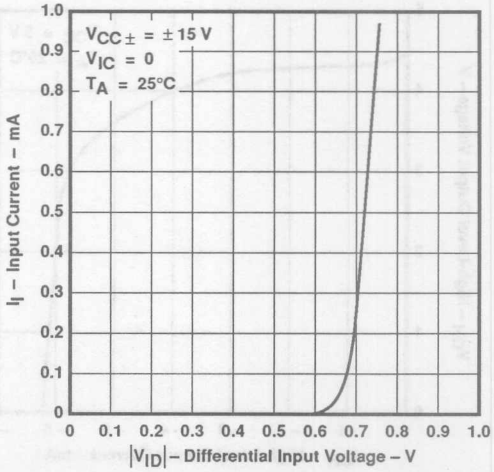


Figure 8

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[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS[†]

MAXIMUM PEAK OUTPUT VOLTAGE
vs
OUTPUT CURRENT

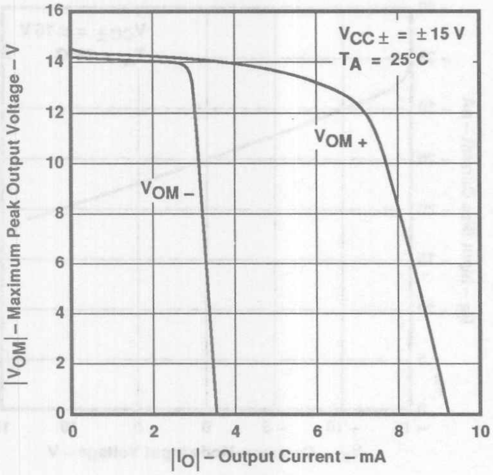

Figure 9

MAXIMUM PEAK OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE

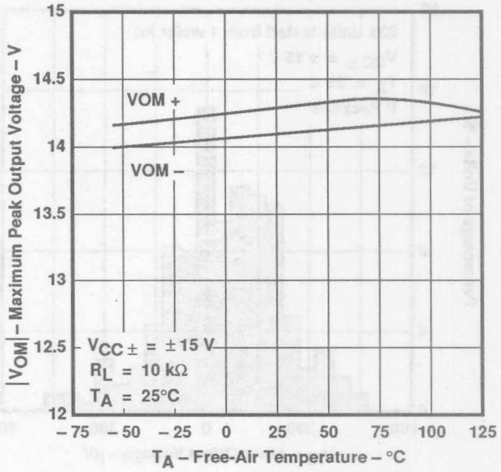

Figure 10

HIGH-LEVEL OUTPUT VOLTAGE
vs
HIGH-LEVEL OUTPUT CURRENT

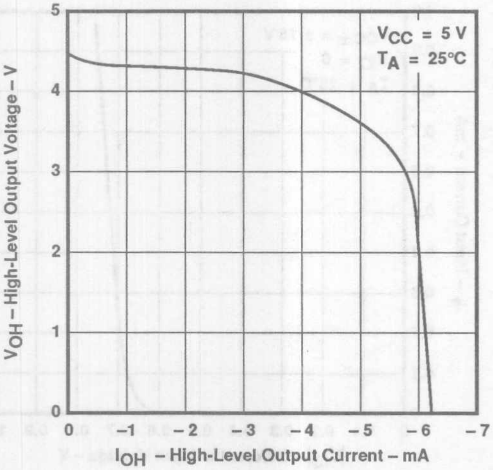

Figure 11

HIGH-LEVEL OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE

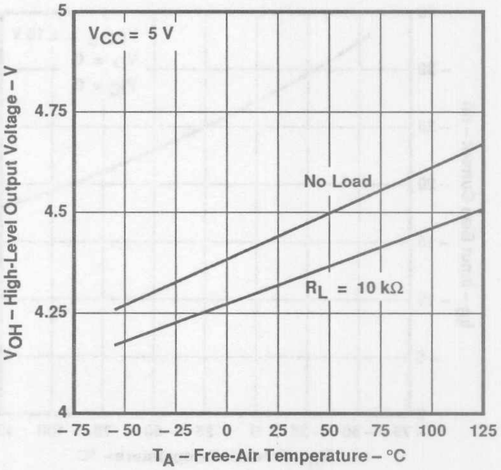

Figure 12

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[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

LOW-LEVEL OUTPUT VOLTAGE
vs
LOW-LEVEL OUTPUT CURRENT

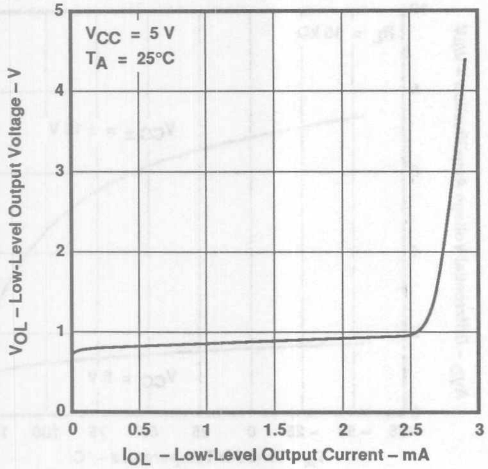

Figure 13

LOW-LEVEL OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE

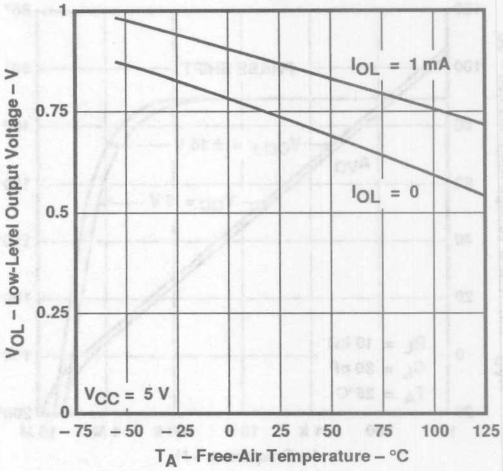

Figure 14

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE
vs
FREQUENCY

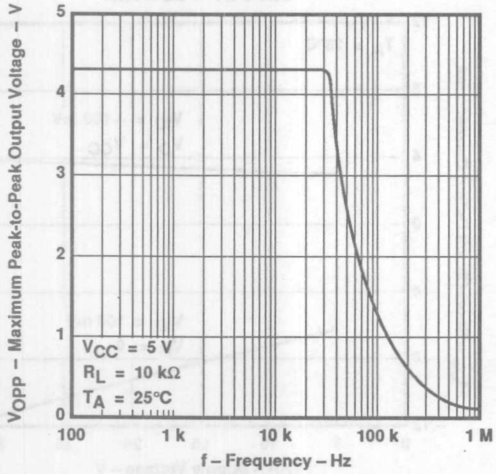

Figure 15

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE
vs
FREQUENCY

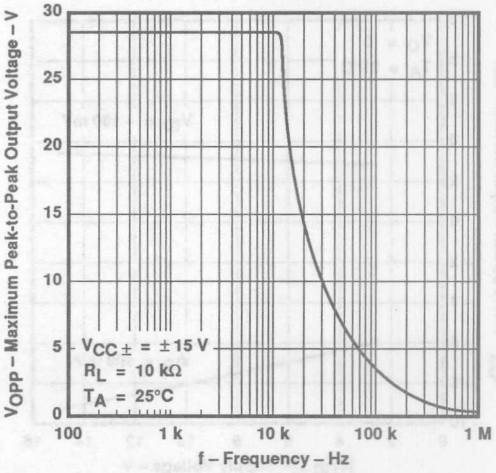

Figure 16

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† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS[†]

LARGE-SIGNAL DIFFERENTIAL VOLTAGE
AMPLIFICATION AND PHASE SHIFT
vs
FREQUENCY

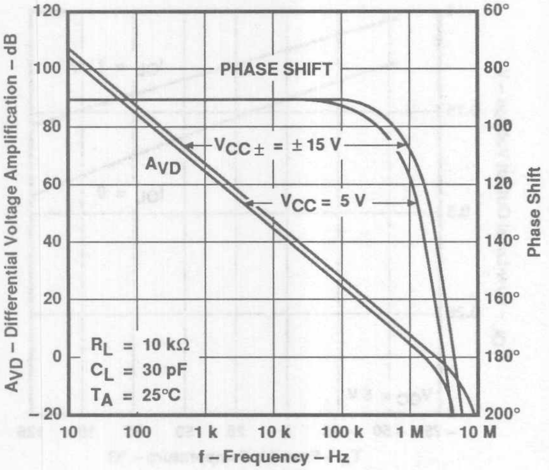

Figure 17

LARGE-SIGNAL DIFFERENTIAL VOLTAGE
AMPLIFICATION
vs
FREE-AIR TEMPERATURE

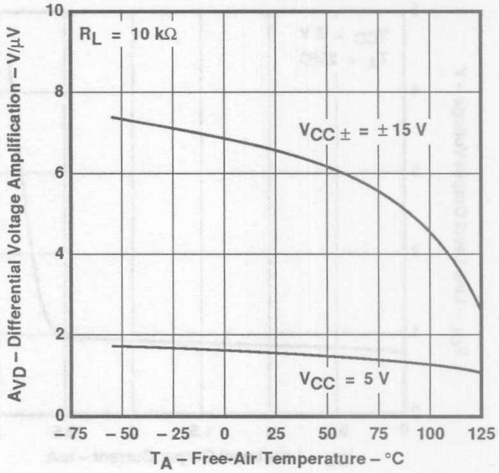

Figure 18

SHORT-CIRCUIT OUTPUT CURRENT
vs
SUPPLY VOLTAGE

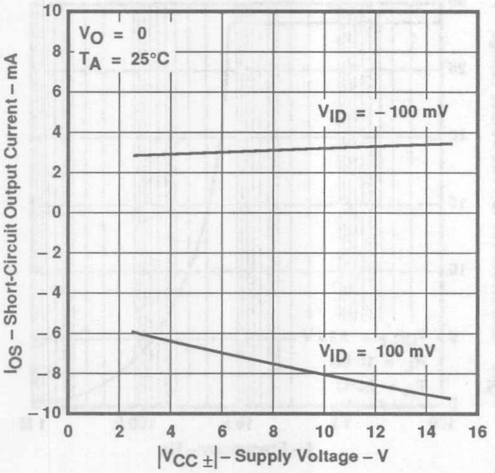

Figure 19

SHORT-CIRCUIT OUTPUT CURRENT
vs
SUPPLY VOLTAGE

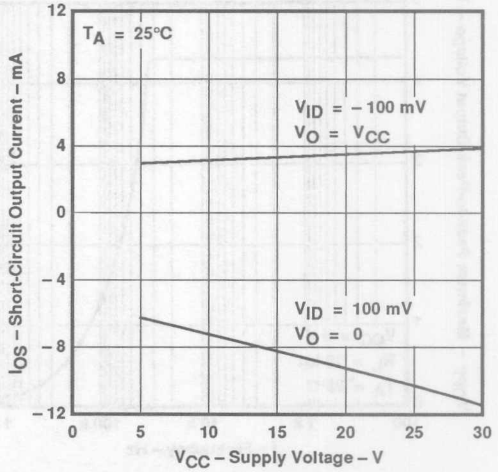

Figure 20

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[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS[†]

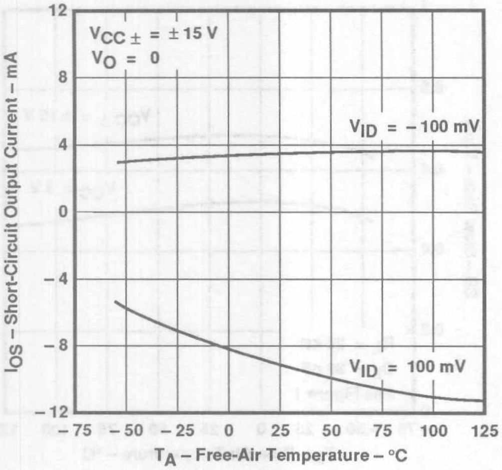
SHORT-CIRCUIT OUTPUT CURRENT
vs
FREE-AIR TEMPERATURE

Figure 21

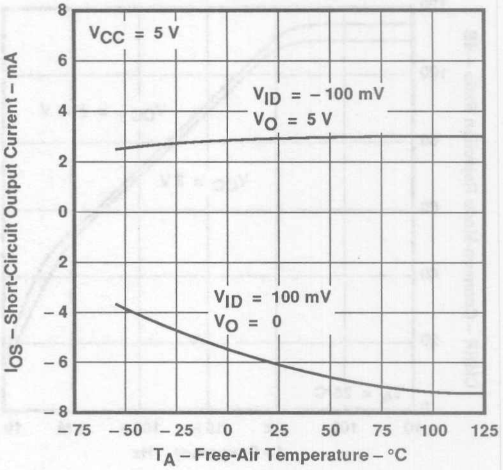
SHORT-CIRCUIT OUTPUT CURRENT
vs
FREE-AIR TEMPERATURE

Figure 22

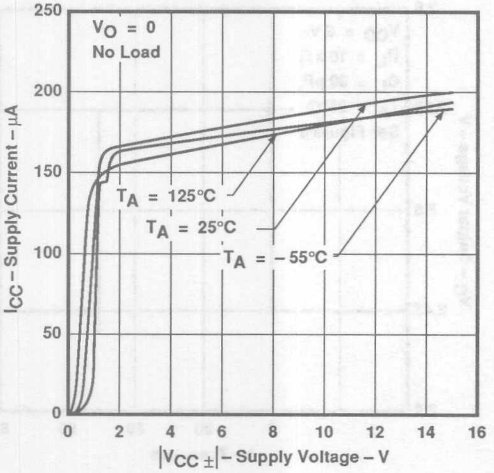
SUPPLY CURRENT
vs
SUPPLY VOLTAGE

Figure 23

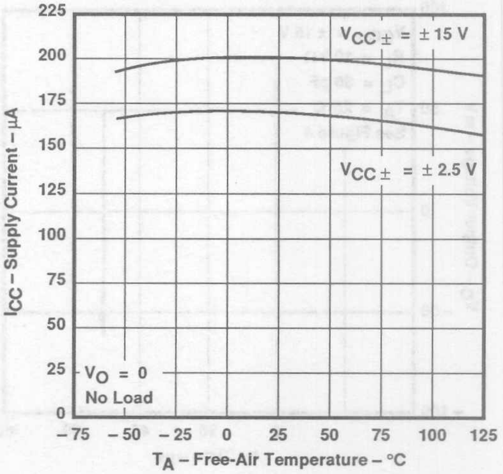
SUPPLY CURRENT
vs
FREE-AIR TEMPERATURE

Figure 24

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[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

COMMON-MODE REJECTION RATIO
vs
FREQUENCY

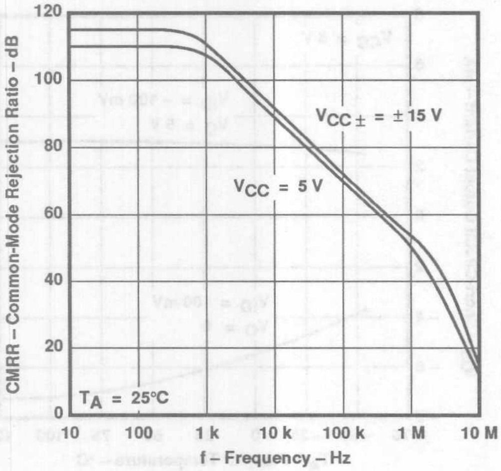

Figure 25

SLEW RATE
vs
FREE-AIR TEMPERATURE

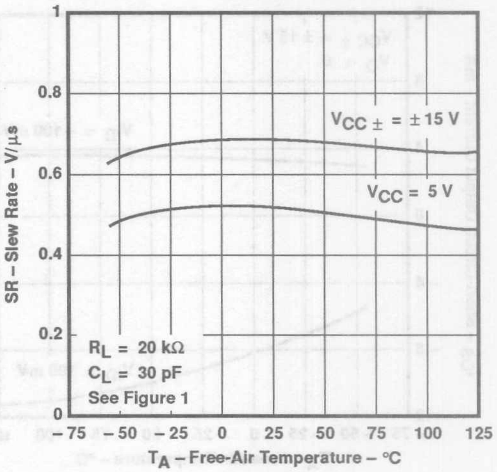

Figure 26

VOLTAGE-FOLLOWER
SMALL-SIGNAL
PULSE RESPONSE

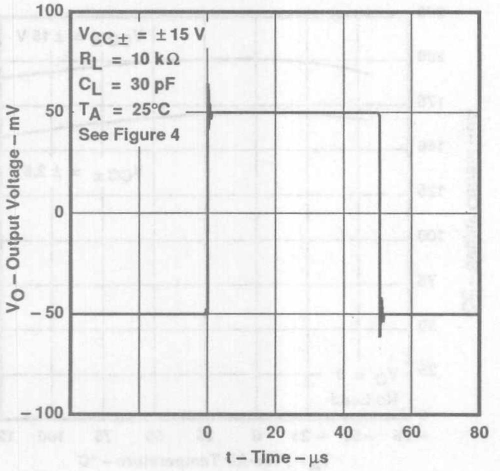

Figure 27

VOLTAGE-FOLLOWER
SMALL-SIGNAL
PULSE RESPONSE

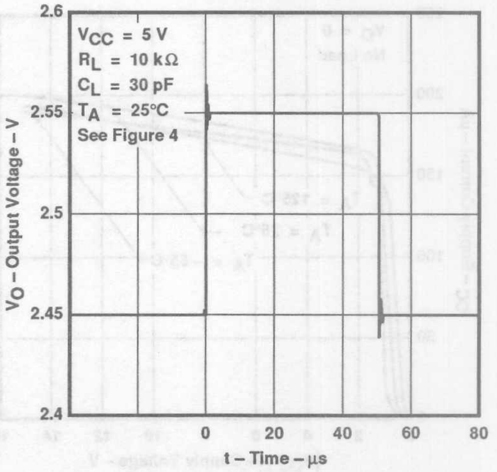

Figure 28

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†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS

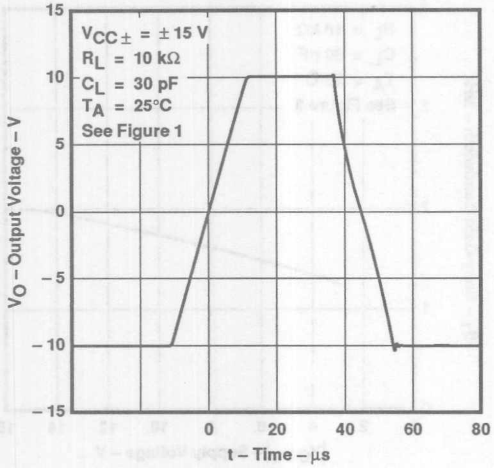
VOLTAGE-FOLLOWER
LARGE-SIGNAL
PULSE RESPONSE

Figure 29

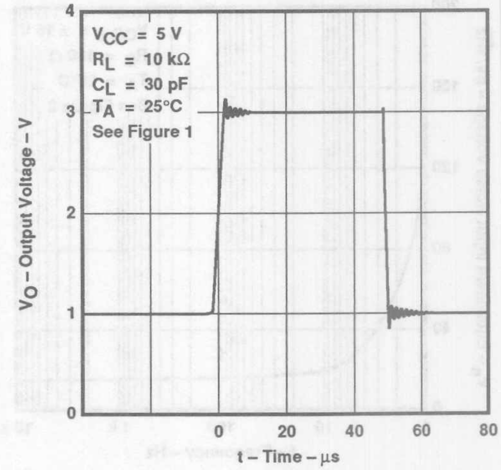
VOLTAGE-FOLLOWER
LARGE-SIGNAL
PULSE RESPONSE

Figure 30

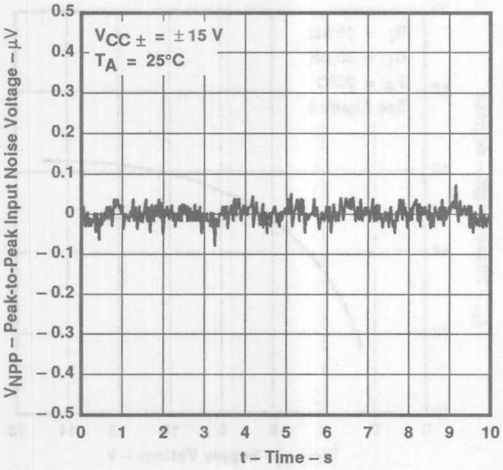
PEAK-TO-PEAK EQUIVALENT
INPUT NOISE VOLTAGE
0.1 TO 1 Hz

Figure 31

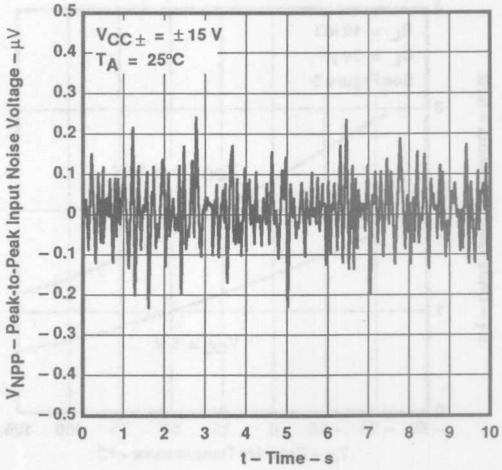
PEAK-TO-PEAK EQUIVALENT
INPUT NOISE VOLTAGE
0.1 TO 10 Hz

Figure 32

## TYPICAL CHARACTERISTICS[†]

EQUIVALENT INPUT NOISE VOLTAGE
vs
FREQUENCY

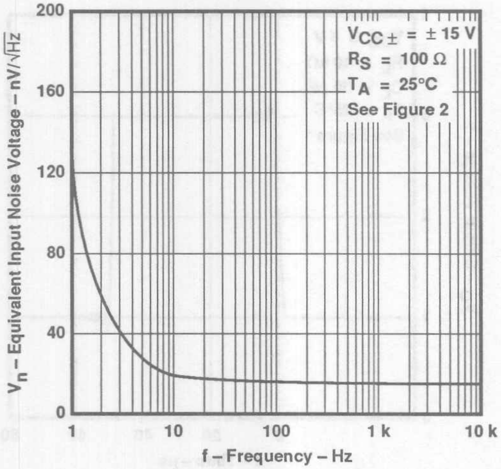

Figure 33

UNITY-GAIN BANDWIDTH
vs
SUPPLY VOLTAGE

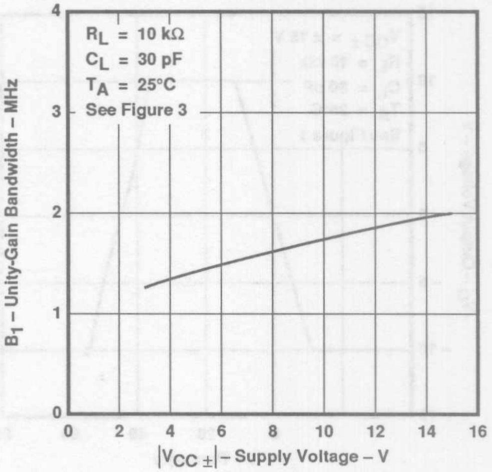

Figure 34

UNITY-GAIN BANDWIDTH
vs
FREE-AIR TEMPERATURE

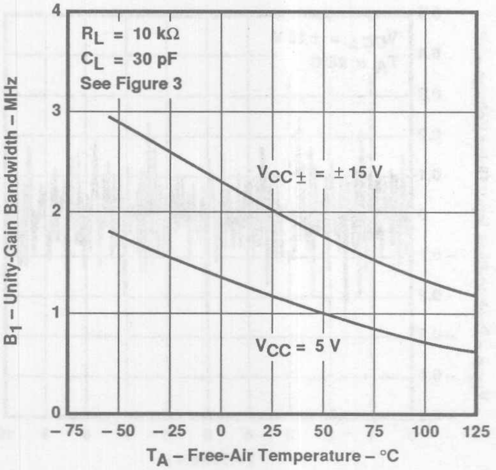

Figure 35

PHASE MARGIN
vs
SUPPLY VOLTAGE

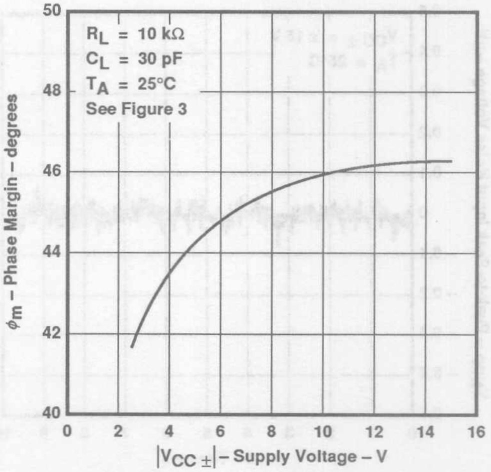

Figure 36

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[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

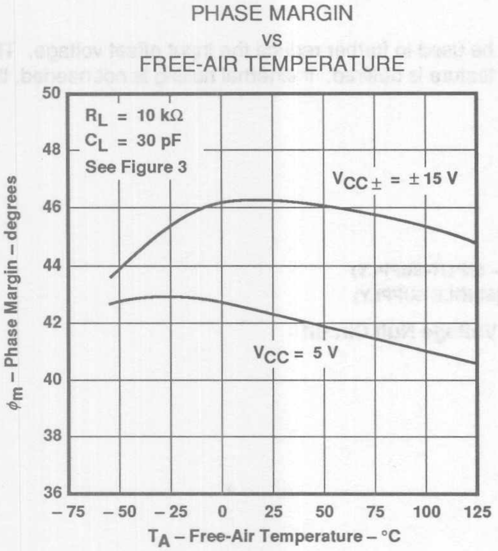

Figure 37

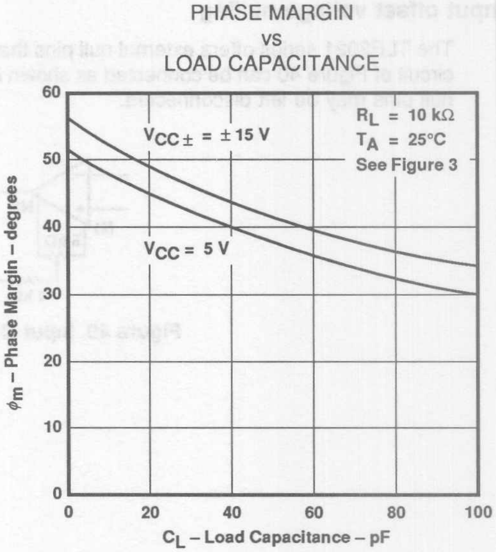

Figure 38

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†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## APPLICATION INFORMATION

### voltage-follower applications

The TLE2021 circuitry includes input protection diodes to limit the voltage across the input transistors; however, no provision is made in the circuit to limit the current if these diodes are forward-biased. Note that this condition can occur when the device is operated in the voltage-follower configuration and driven with a fast, large-signal pulse. It is recommended that a feedback resistor be used to limit the current to a maximum of 1 mA to prevent degradation of the device. Also, remember that this feedback resistor will form a pole with the input capacitance of the device. For feedback resistor values greater than 10 kΩ, this pole will degrade the amplifier's phase margin. This problem can be alleviated by adding a capacitor (20 pF to 50 pF) in parallel with the feedback resistor (see Figure 39).

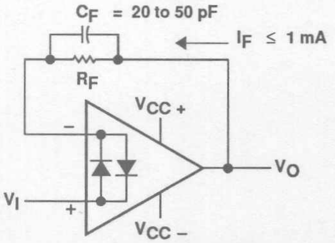


Figure 39. Voltage Follower

## APPLICATION INFORMATION

### input offset voltage nulling

The TLE2021 series offers external null pins that can be used to further reduce the input offset voltage. The circuit of Figure 40 can be connected as shown if this feature is desired. If external nulling is not needed, the null pins may be left disconnected.

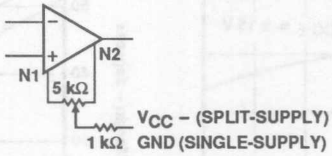


Figure 40. Input Offset Voltage Null Circuit

# TLE2022, TLE2022A, TLE2022B
# EXCALIBUR HIGH-SPEED LOW-POWER PRECISION DUAL OPERATIONAL AMPLIFIERS

D3264, MAY 1989 – REVISED FEBRUARY 1991

## available features

- **Supply Current . . . 500 µA Max**
- **High Unity-Gain Bandwidth . . . 2.8 MHz Typ**
- **High Slew Rate . . . 0.7 V/µs Min**
- **Supply Current Change Over Military Temp Range . . . 37 µA Typ**
- **Specified for Both 5-V Single-Supply and ± 15-V Operation**
- **Phase-Reversal Protection**
- **High Open-Loop Gain . . . 10 V/µV (140 dB) Typ**
- **Low Offset Voltage . . . 150 µV Max**
- **Offset Voltage Drift With Time . . . 0.005 µV/mo Typ**
- **Low Input Bias Current . . . 50 nA Max**
- **Low Noise Voltage . . . 19 nV/$\sqrt{Hz}$ Typ at f = 10 Hz**

## description

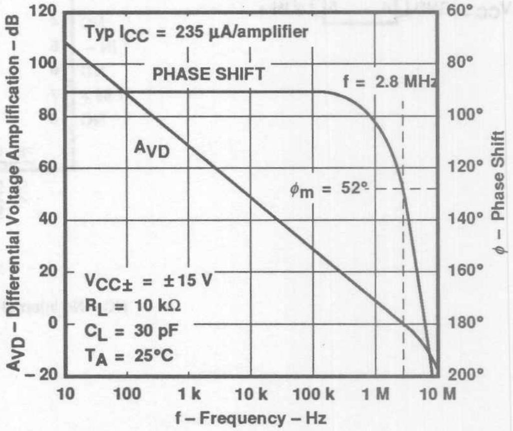
The TLE2022, TLE2022A, and TLE2022B devices are precision, high-speed, low-power operational amplifiers using Texas Instruments patent-pending Excalibur process. These devices combine the best features of the OP221 with highly improved slew rate and unity-gain bandwidth.

The complementary bipolar Excalibur process utilizes isolated vertical P-N-P transistors that yield dramatic improvement in unity-gain bandwidth and slew rate over similar devices.

The addition of a patent-pending bias circuit in conjunction with this process results in extremely stable parameters with both time and temperature. This means that a "precision" device remains a precision device even with changes in temperature and over years of use.

This combination of excellent dc performance with a common-mode input voltage range that includes the negative rail makes these devices

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION and PHASE SHIFT vs FREQUENCY



AVAILABLE OPTIONS

| $T_A$ | $V_{IO}$ max AT 25°C | PACKAGE | | | | |
|---|---|---|---|---|---|---|
| | | SMALL-OUTLINE (D) | CHIP CARRIER (FK) | CERAMIC DIP (JG) | METAL CAN (L) | PLASTIC DIP (P) |
| 0°C to 70°C | 300 µV | TLE2022ACD | — | — | — | TLE2022ACP |
| | 500 µV | TLE2022CD | — | — | — | TLE2022CP |
| – 40°C to 85°C | 300 µV | TLE2022AID | — | — | — | TLE2022AIP |
| | 500 µV | TLE2022ID | — | — | — | TLE2022IP |
| – 55°C to 125°C | 150 µV | — | — | TLE2022BMJG | TLE2022BML | — |
| | 300 µV | TLE2022AMD | TLE2022AMFK | TLE2022AMJG | TLE2022AML | TLE2022AMP |
| | 500 µV | TLE2022MD | TLE2022MFK | TLE2022MJG | TLE2022ML | TLE2022MP |

D packages are available taped and reeled. Add "R" suffix to device type, (e.g.,TLE2022ACDR).

PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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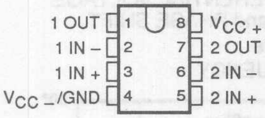
## description (continued)

the ideal choice for low-level signal conditioning applications in either single-supply or split-supply configurations. In addition, these devices offer phase-reversal protection circuitry that eliminates an unexpected change in output states when one of the inputs goes below the negative supply rail.

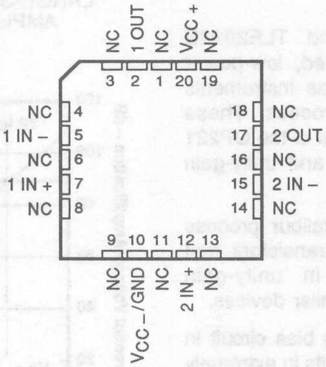
Available packaging options include small-outline and chip-carrier versions for high-density systems applications.

The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from −40°C to 85°C. The M-suffix devices are characterized for operation over the full military temperature range of −55°C to 125°C.

**D, JG, or P PACKAGE**
**(TOP VIEW)**

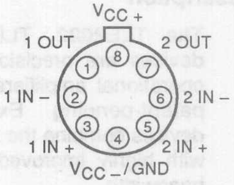


**FK PACKAGE**
**(TOP VIEW)**



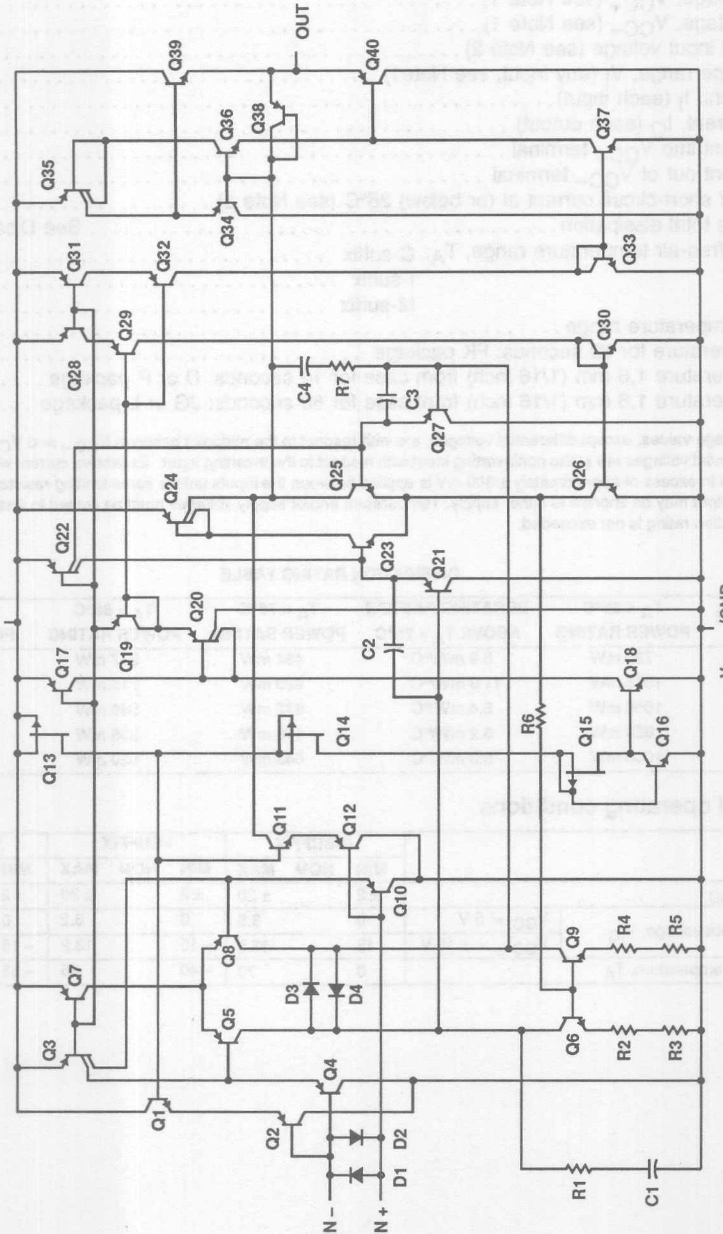
NC – No internal connection

**L PACKAGE**
**(TOP VIEW)**



Pin 4 of the L package is in electrical contact with the case.

## equivalent schematic (each amplifier)



## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | | |
|---|---|---|
| Supply voltage, $V_{CC+}$ (see Note 1) | | 20 V |
| Supply voltage, $V_{CC-}$ (see Note 1) | | −20 V |
| Differential input voltage (see Note 2) | | ±0.6 V |
| Input voltage range, $V_I$ (any input, see Note1) | | $V_{CC\pm}$ |
| Input current, $I_I$ (each input) | | ±1 mA |
| Output current, $I_O$ (each output) | | ±30 mA |
| Total current into $V_{CC+}$ terminal | | 80 mA |
| Total current out of $V_{CC-}$ terminal | | 80 mA |
| Duration of short-circuit current at (or below) 25°C (see Note 3) | | unlimited |
| Continuous total dissipation | | See Dissipation Rating Table |
| Operating free-air temperature range, $T_A$: | C-suffix | 0°C to 70°C |
| | I-suffix | −40°C to 85°C |
| | M-suffix | −55°C to 125°C |
| Storage temperature range | | −65°C to 150°C |
| Case temperature for 60 seconds: FK package | | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package | | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG or L package | | 300°C |

NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between $V_{CC+}$ and $V_{CC-}$.

2. Differential voltages are at the noninverting input with respect to the inverting input. Excessive current will flow if a differential input voltage in excess of approximately ± 600 mV is applied between the inputs unless some limiting resistance is used.

3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25°C$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25°C$ | $T_A = 70°C$ POWER RATING | $T_A = 85°C$ POWER RATING | $T_A = 125°C$ POWER RATING |
|---|---|---|---|---|---|
| D | 725 mW | 5.8 mW/°C | 464 mW | 377 mW | 145 mW |
| FK | 1375 mW | 11.0 mW/°C | 880 mW | 715 mW | 275 mW |
| JG | 1050 mW | 8.4 mW/°C | 672 mW | 546 mW | 210 mW |
| L | 650 mW | 5.2 mW/°C | 416 mW | 338 mW | 130 mW |
| P | 1000 mW | 8.0 mW/°C | 640 mW | 520 mW | 200 mW |

## recommended operating conditions

| | | C-SUFFIX | | | I-SUFFIX | | | M-SUFFIX | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MIN | NOM | MAX | MIN | NOM | MAX | MIN | NOM | MAX | |
| Supply voltage, $V_{CC}$ | | ± 2 | | ± 20 | ± 2 | | ± 20 | ± 2 | | ± 20 | V |
| Common-mode input voltage, $V_{IC}$ | $V_{CC} = 5$ V | 0 | | 3.5 | 0 | | 3.2 | 0 | | 3.2 | V |
| | $V_{CC\pm} = \pm 15$ V | − 15 | | 13.5 | − 15 | | 13.2 | − 15 | | 13.2 | |
| Operating free-air temperature, $T_A$ | | 0 | | 70 | − 40 | | 85 | − 55 | | 125 | °C |

### electrical characteristics at specified free-air temperature, $V_{CC}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2022 | | | TLE2022A | | | TLE2022B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC}$ = 0, $R_S$ = 50 Ω | 25°C | | | 600 | | | 400 | | | 250 | µV |
| | | | Full range | | | 800 | | | 550 | | | 400 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 2 | | | 2 | | | 2 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.005 | | | 0.005 | | | 0.005 | | µV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 0.5 | 5 | | 0.4 | 4 | | 0.3 | 3 | nA |
| | | | Full range | | | 5 | | | 4 | | | 3 | |
| $I_{IB}$ | Input bias current | | 25°C | | 35 | 60 | | 33 | 55 | | 30 | 50 | nA |
| | | | Full range | | | 60 | | | 55 | | | 50 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S$ = 50 Ω | 25°C | 0 to 3.5 | −0.3 to 4 | | 0 to 3.5 | −0.3 to 4 | | 0 to 3.5 | −0.3 to 4 | | V |
| | | | Full range | 0 to 3.5 | | | 0 to 3.5 | | | 0 to 3.5 | | | |
| $V_{OH}$ | High-level output voltage | $R_L$ = 10 kΩ | 25°C | 4 | 4.3 | | 4 | 4.3 | | 4 | 4.3 | | V |
| | | | Full range | 3.9 | | | 3.9 | | | 3.9 | | | |
| $V_{OL}$ | Low-level output voltage | | 25°C | | 0.7 | 0.8 | | 0.7 | 0.8 | | 0.7 | 0.8 | V |
| | | | Full range | | | 0.85 | | | 0.85 | | | 0.85 | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O$ = 1.4 V to 4 V, $R_L$ = 10 kΩ | 25°C | 0.3 | 1.5 | | 0.4 | 1.5 | | 0.5 | 1.5 | | V/µV |
| | | | Full range | 0.3 | | | 0.4 | | | 0.5 | | | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min, $R_S$ = 50 Ω | 25°C | 85 | 100 | | 87 | 102 | | 90 | 105 | | dB |
| | | | Full range | 80 | | | 82 | | | 85 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC}$ = 5 V to 30 V | 25°C | 100 | 115 | | 103 | 118 | | 105 | 120 | | dB |
| | | | Full range | 95 | | | 98 | | | 100 | | | |
| $I_{CC}$ | Supply current | $V_O$ = 2.5 V, No load | 25°C | | 400 | 500 | | 400 | 500 | | 400 | 500 | µA |
| | | | Full range | | | 500 | | | 500 | | | 500 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | Full range | | 7 | | | 7 | | | 7 | | µA |

†Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A$ = 150°C extrapolated to $T_A$ = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TLE2022 | | | TLE2022A | | | TLE2022B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC} = 0$, | $R_S = 50\ \Omega$ | 25°C | | 150 | 500 | | 120 | 300 | | 70 | 150 | μV |
| | | | | Full range | | | 700 | | | 450 | | | 300 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 2 | | | 2 | | | 2 | | μV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.006 | | | 0.006 | | | 0.006 | | μV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 0.5 | 5 | | 0.4 | 4 | | 0.3 | 3 | nA |
| | | | | Full range | | | 5 | | | 4 | | | 3 | |
| $I_{IB}$ | Input bias current | | | 25°C | | 35 | 60 | | 33 | 55 | | 30 | 50 | nA |
| | | | | Full range | | | 60 | | | 55 | | | 50 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | | 25°C | −15<br>to<br>13.5 | −15.3<br>to<br>14 | | −15<br>to<br>13.5 | −15.3<br>to<br>14 | | −15<br>to<br>13.5 | −15.3<br>to<br>14 | | V |
| | | | | Full range | −15<br>to<br>13.5 | | | −15<br>to<br>13.5 | | | −15<br>to<br>13.5 | | | |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $R_L = 10\ k\Omega$ | | 25°C | 14 | 14.3 | | 14 | 14.3 | | 14 | 14.3 | | V |
| | | | | Full range | 13.9 | | | 13.9 | | | 13.9 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | | 25°C | −13.7 | −14.1 | | −13.7 | −14.1 | | −13.7 | −14.1 | | V |
| | | | | Full range | −13.7 | | | −13.7 | | | −13.7 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = \pm 10$ V, | $R_L = 10\ k\Omega$ | 25°C | 0.8 | 4 | | 1 | 7 | | 1.5 | 10 | | V/μV |
| | | | | Full range | 0.8 | | | 1 | | | 1.5 | | | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min, | $R_S = 50\ \Omega$ | 25°C | 95 | 106 | | 97 | 109 | | 100 | 112 | | dB |
| | | | | Full range | 91 | | | 93 | | | 96 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 2.5$ V to ± 15 V | | 25°C | 100 | 115 | | 103 | 118 | | 105 | 120 | | dB |
| | | | | Full range | 95 | | | 98 | | | 100 | | | |
| $I_{CC}$ | Supply current | $V_O = 0$, | No load | 25°C | | 470 | 600 | | 470 | 600 | | 470 | 600 | μA |
| | | | | Full range | | | 600 | | | 600 | | | 600 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | | Full range | | 9 | | | 9 | | | 9 | | μA |

†Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150$°C extrapolated to $T_A = 25$°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC} = 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$ | TLE2022 | | | TLE2022A | | | TLE2022B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O = 1$ V to 3 V, See Figure 1 | 25°C | | 0.5 | | | 0.5 | | | 0.5 | | V/μs |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz | 25°C | | 21 | 50 | | 21 | 50 | | 21 | 50 | nV/√Hz |
| | | f = 1 kHz | 25°C | | 17 | 30 | | 17 | 30 | | 17 | 30 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.16 | | | 0.16 | | | 0.16 | | μV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.47 | | | 0.47 | | | 0.47 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.1 | | | 0.1 | | | 0.1 | | pA/√Hz |
| $B_1$ | Unity-gain bandwidth | See Figure 3 | 25°C | | 1.7 | | | 1.7 | | | 1.7 | | MHz |
| $\phi_m$ | Phase margin at unity gain | See Figure 3 | 25°C | | 47° | | | 47° | | | 47° | | |

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2022 | | | TLE2022A | | | TLE2022B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O = \pm 10$ V, See Figure 1 | 25°C | 0.45 | 0.65 | | 0.45 | 0.65 | | 0.45 | 0.65 | | V/μs |
| | | | Full range | 0.45 | | | 0.45 | | | 0.45 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz | 25°C | | 19 | 50 | | 19 | 50 | | 19 | 50 | nV/√Hz |
| | | f = 1 kHz | 25°C | | 15 | 30 | | 15 | 30 | | 15 | 30 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.16 | | | 0.16 | | | 0.16 | | μV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.47 | | | 0.47 | | | 0.47 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.1 | | | 0.1 | | | 0.1 | | pA/√Hz |
| $B_1$ | Unity-gain bandwidth | See Figure 3 | 25°C | | 2.8 | | | 2.8 | | | 2.8 | | MHz |
| $\phi_m$ | Phase margin at unity gain | See Figure 3 | 25°C | | 52° | | | 52° | | | 52° | | |

†Full range is 0°C to 70°C.

### electrical characteristics at specified free-air temperature, $V_{CC}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$[†] | TLE2022 | | | TLE2022A | | | TLE2022B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC}$ = 0, $R_S$ = 50 Ω | 25°C | | | 600 | | | 400 | | | 250 | μV |
| | | | Full range | | | 800 | | | 550 | | | 400 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 2 | | | 2 | | | 2 | | μV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.005 | | | 0.005 | | | 0.005 | | μV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 0.5 | 5 | | 0.4 | 4 | | 0.3 | 3 | nA |
| | | | Full range | | | 5 | | | 4 | | | 3 | |
| $I_{IB}$ | Input bias current | | 25°C | | 35 | 60 | | 33 | 55 | | 30 | 50 | nA |
| | | | Full range | | | 60 | | | 55 | | | 50 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S$ = 50 Ω | 25°C | 0<br>to<br>3.5 | −0.3<br>to<br>4 | | 0<br>to<br>3.5 | −0.3<br>to<br>4 | | 0<br>to<br>3.5 | −0.3<br>to<br>4 | | V |
| | | | Full range | 0<br>to<br>3.2 | | | 0<br>to<br>3.2 | | | 0<br>to<br>3.2 | | | |
| $V_{OH}$ | High-level output voltage | $R_L$ = 10 kΩ | 25°C | 4 | 4.3 | | 4 | 4.3 | | 4 | 4.3 | | V |
| | | | Full range | 3.9 | | | 3.9 | | | 3.9 | | | |
| $V_{OL}$ | Low-level output voltage | | 25°C | | 0.7 | 0.8 | | 0.7 | 0.8 | | 0.7 | 0.8 | V |
| | | | Full range | | | 0.9 | | | 0.9 | | | 0.9 | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O$ = 1.4 V to 4 V, $R_L$ = 10 kΩ | 25°C | 0.3 | 1.5 | | 0.4 | 1.5 | | 0.5 | 1.5 | | V/μV |
| | | | Full range | 0.2 | | | 0.2 | | | 0.2 | | | |
| CMRR | Common-mode rejection ratio | $V_{IC}$ = $V_{ICR}$ min, $R_S$ = 50 Ω | 25°C | 85 | 100 | | 87 | 102 | | 90 | 105 | | dB |
| | | | Full range | 80 | | | 82 | | | 85 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC}$ = 5 V to 30 V | 25°C | 100 | 115 | | 103 | 118 | | 105 | 120 | | dB |
| | | | Full range | 95 | | | 98 | | | 100 | | | |
| $I_{CC}$ | Supply current | $V_O$ = 2.5 V, No load | 25°C | | 400 | 500 | | 400 | 500 | | 400 | 500 | μA |
| | | | Full range | | | 500 | | | 500 | | | 500 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | Full range | | 15 | | | 15 | | | 15 | | μA |

[†] Full range is − 40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A$ = 150°C extrapolated to $T_A$ = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC} = 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$ | TLE2022 | | | TLE2022A | | | TLE2022B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O = 1$ V to 3 V, See Figure 1 | 25°C | | 0.5 | | | 0.5 | | | 0.5 | | V/μs |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz | 25°C | | 21 | 50 | | 21 | 50 | | 21 | 50 | nV/√Hz |
| | | f = 1 kHz | 25°C | | 17 | 30 | | 17 | 30 | | 17 | 30 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.16 | | | 0.16 | | | 0.16 | | μV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.47 | | | 0.47 | | | 0.47 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.1 | | | 0.1 | | | 0.1 | | pA/√Hz |
| $B_1$ | Unity-gain bandwidth | See Figure 3 | 25°C | | 1.7 | | | 1.7 | | | 1.7 | | MHz |
| $\phi_m$ | Phase margin at unity gain | See Figure 3 | 25°C | | 47° | | | 47° | | | 47° | | |

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2022 | | | TLE2022A | | | TLE2022B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O = \pm 10$ V, See Figure 1 | 25°C | 0.45 | 0.65 | | 0.45 | 0.65 | | 0.45 | 0.65 | | V/μs |
| | | | Full range | 0.42 | | | 0.42 | | | 0.42 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz | 25°C | | 19 | 50 | | 19 | 50 | | 19 | 50 | nV/√Hz |
| | | f = 1 kHz | 25°C | | 15 | 30 | | 15 | 30 | | 15 | 30 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.16 | | | 0.16 | | | 0.16 | | μV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.47 | | | 0.47 | | | 0.47 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.1 | | | 0.1 | | | 0.1 | | pA/√Hz |
| $B_1$ | Unity-gain bandwidth | See Figure 3 | 25°C | | 2.8 | | | 2.8 | | | 2.8 | | MHz |
| $\phi_m$ | Phase margin at unity gain | See Figure 3 | 25°C | | 52° | | | 52° | | | 52° | | |

† Full range is – 40°C to 85°C.

## operating characteristics at specified free-air temperature, $V_{CC} = 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$ | TLE2022 | | | TLE2022A | | | TLE2022B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O = 1$ V to 3 V, See Figure 1 | 25°C | | 0.5 | | | 0.5 | | | 0.5 | | V/μs |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz | 25°C | | 21 | 50 | | 21 | 50 | | 21 | 50 | nV/√Hz |
| | | f = 1 kHz | 25°C | | 17 | 30 | | 17 | 30 | | 17 | 30 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.16 | | | 0.16 | | | 0.16 | | μV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.47 | | | 0.47 | | | 0.47 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.1 | | | 0.1 | | | 0.1 | | pA/√Hz |
| $B_1$ | Unity-gain bandwidth | See Figure 3 | 25°C | | 1.7 | | | 1.7 | | | 1.7 | | MHz |
| $\phi_m$ | Phase margin at unity gain | See Figure 3 | 25°C | | 47° | | | 47° | | | 47° | | |

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$[†] | TLE2022 | | | TLE2022A | | | TLE2022B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O = \pm 10$ V, See Figure 1 | 25°C | 0.45 | 0.65 | | 0.45 | 0.65 | | 0.45 | 0.65 | | V/μs |
| | | | Full range | 0.42 | | | 0.42 | | | 0.42 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz | 25°C | | 19 | 50 | | 19 | 50 | | 19 | 50 | nV/√Hz |
| | | f = 1 kHz | 25°C | | 15 | 30 | | 15 | 30 | | 15 | 30 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.16 | | | 0.16 | | | 0.16 | | μV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.47 | | | 0.47 | | | 0.47 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.1 | | | 0.1 | | | 0.1 | | pA/√Hz |
| $B_1$ | Unity-gain bandwidth | See Figure 3 | 25°C | | 2.8 | | | 2.8 | | | 2.8 | | MHz |
| $\phi_m$ | Phase margin at unity gain | See Figure 3 | 25°C | | 52° | | | 52° | | | 52° | | |

[†] Full range is – 40°C to 85°C.

## electrical characteristics at specified free-air temperature, $V_{CC}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TLE2022 | | | TLE2022A | | | TLE2022B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC}$ = 0, | $R_S$ = 50 Ω | 25°C | | | 600 | | | 400 | | | 250 | µV |
| | | | | Full range | | | 800 | | | 550 | | | 400 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 2 | | | 2 | | | 2 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.005 | | | 0.005 | | | 0.005 | | µV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 0.5 | 5 | | 0.4 | 4 | | 0.3 | 3 | nA |
| | | | | Full range | | | 5 | | | 4 | | | 3 | |
| $I_{IB}$ | Input bias current | | | 25°C | | 35 | 60 | | 33 | 55 | | 30 | 50 | nA |
| | | | | Full range | | | 60 | | | 55 | | | 50 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S$ = 50 Ω | | 25°C | 0<br>to<br>3.5 | −0.3<br>to<br>4 | | 0<br>to<br>3.5 | −0.3<br>to<br>4 | | 0<br>to<br>3.5 | −0.3<br>to<br>4 | | V |
| | | | | Full range | 0<br>to<br>3.2 | | | 0<br>to<br>3.2 | | | 0<br>to<br>3.2 | | | |
| $V_{OH}$ | High-level output voltage | $R_L$ = 10 kΩ | | 25°C | 4 | 4.3 | | 4 | 4.3 | | 4 | 4.3 | | V |
| | | | | Full range | 3.8 | | | 3.8 | | | 3.8 | | | |
| $V_{OL}$ | Low-level output voltage | | | 25°C | | 0.7 | 0.8 | | 0.7 | 0.8 | | 0.7 | 0.8 | V |
| | | | | Full range | | | 0.95 | | | 0.95 | | | 0.95 | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O$ = 1.4 V to 4 V, | $R_L$ = 10 kΩ | 25°C | 0.3 | 1.5 | | 0.4 | 1.5 | | 0.5 | 1.5 | | V/µV |
| | | | | Full range | 0.1 | | | 0.1 | | | 0.1 | | | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min, | $R_S$ = 50 Ω | 25°C | 85 | 100 | | 87 | 102 | | 90 | 105 | | dB |
| | | | | Full range | 80 | | | 82 | | | 85 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC}$ = 5 V to 30 V | | 25°C | 100 | 115 | | 103 | 118 | | 105 | 120 | | dB |
| | | | | Full range | 95 | | | 98 | | | 100 | | | |
| $I_{CC}$ | Supply current | $V_O$ = 2.5 V, | No load | 25°C | | 400 | 500 | | 400 | 500 | | 400 | 500 | µA |
| | | | | Full range | | | 500 | | | 500 | | | 500 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | | Full range | | 37 | | | 37 | | | 37 | | µA |

†Full range is – 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A$ = 150°C extrapolated to $T_A$ = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## electrical characteristics at specified free-air temperature, $V_{CC\pm}$ = ± 15 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2022 | | | TLE2022A | | | TLE2022B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC}$ = 0, $R_S$ = 50 Ω | 25°C | | 150 | 500 | | 120 | 300 | | 70 | 150 | µV |
| | | | Full range | | | 700 | | | 450 | | | 300 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 2 | | | 2 | | | 2 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.006 | | | 0.006 | | | 0.006 | | µV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 0.5 | 5 | | 0.4 | 4 | | 0.3 | 3 | nA |
| | | | Full range | | | 5 | | | 4 | | | 3 | |
| $I_{IB}$ | Input bias current | | 25°C | | 35 | 60 | | 33 | 55 | | 30 | 50 | nA |
| | | | Full range | | | 60 | | | 55 | | | 50 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S$ = 50 Ω | 25°C | – 15<br>to<br>13.5 | – 15.3<br>to<br>14 | | – 15<br>to<br>13.5 | – 15.3<br>to<br>14 | | – 15<br>to<br>13.5 | – 15.3<br>to<br>14 | | V |
| | | | Full range | – 15<br>to<br>13.2 | | | – 15<br>to<br>13.2 | | | – 15<br>to<br>13.2 | | | |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $R_L$ = 10 kΩ | 25°C | 14 | 14.3 | | 14 | 14.3 | | 14 | 14.3 | | V |
| | | | Full range | 13.9 | | | 13.9 | | | 13.9 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | 25°C | – 13.7 | – 14.1 | | – 13.7 | – 14.1 | | – 13.7 | – 14.1 | | V |
| | | | Full range | – 13.6 | | | – 13.6 | | | – 13.6 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O$ = ± 10 V, $R_L$ = 10 kΩ | 25°C | 0.8 | 4 | | 1 | 7 | | 1.5 | 10 | | V/µV |
| | | | Full range | 0.8 | | | 1 | | | 1.5 | | | |
| CMRR | Common-mode rejection ratio | $V_{IC}$ = $V_{ICR}$ min, $R_S$ = 50 Ω | 25°C | 95 | 106 | | 97 | 109 | | 100 | 112 | | dB |
| | | | Full range | 91 | | | 93 | | | 96 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm}$ = ± 2.5 V to ± 15 V | 25°C | 100 | 115 | | 103 | 118 | | 105 | 120 | | dB |
| | | | Full range | 95 | | | 98 | | | 100 | | | |
| $I_{CC}$ | Supply current | $V_O$ = 0, No load | 25°C | | 470 | 600 | | 470 | 600 | | 470 | 600 | µA |
| | | | Full range | | | 600 | | | 600 | | | 600 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | Full range | | 60 | | | 60 | | | 60 | | µA |

† Full range is – 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A$ = 150°C extrapolated to $T_A$ = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC}$ = 5 V (unless otherwise noted)

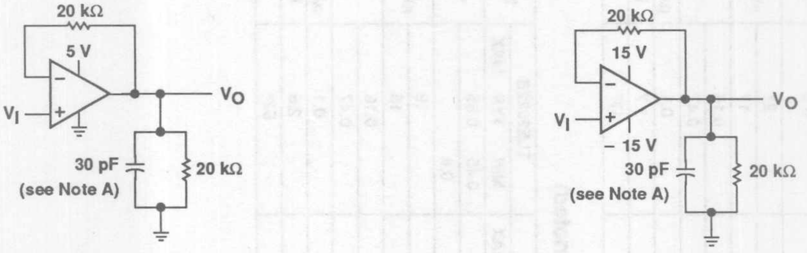
| PARAMETER | | TEST CONDITIONS | $T_A$ | TLE2022 | | | TLE2022A | | | TLE2022B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O$ = 1 V to 3 V, See Figure 1 | 25°C | | 0.5 | | | 0.5 | | | 0.5 | | V/μs |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz | 25°C | | 21 | | | 21 | | | 21 | | $\mathrm{nV}/\sqrt{\mathrm{Hz}}$ |
| | | f = 1 kHz | 25°C | | 17 | | | 17 | | | 17 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.16 | | | 0.16 | | | 0.16 | | μV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.47 | | | 0.47 | | | 0.47 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.1 | | | 0.1 | | | 0.1 | | $\mathrm{pA}/\sqrt{\mathrm{Hz}}$ |
| $B_1$ | Unity-gain bandwidth | See Figure 3 | 25°C | | 1.7 | | | 1.7 | | | 1.7 | | MHz |
| $\phi_m$ | Phase margin at unity gain | See Figure 3 | 25°C | | 47° | | | 47° | | | 47° | | |

## operating characteristics at specified free-air temperature, $V_{CC\pm}$ = ± 15 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2022 | | | TLE2022A | | | TLE2022B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O$ = ± 10 V, See Figure 1 | 25°C | 0.45 | 0.65 | | 0.45 | 0.65 | | 0.45 | 0.65 | | V/μs |
| | | | Full range | 0.4 | | | 0.4 | | | 0.4 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz | 25°C | | 19 | | | 19 | | | 19 | | $\mathrm{nV}/\sqrt{\mathrm{Hz}}$ |
| | | f = 1 kHz | 25°C | | 15 | | | 15 | | | 15 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.16 | | | 0.16 | | | 0.16 | | μV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.47 | | | 0.47 | | | 0.47 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.1 | | | 0.1 | | | 0.1 | | $\mathrm{pA}/\sqrt{\mathrm{Hz}}$ |
| $B_1$ | Unity-gain bandwidth | See Figure 3 | 25°C | | 2.8 | | | 2.8 | | | 2.8 | | MHz |
| $\phi_m$ | Phase margin at unity gain | See Figure 3 | 25°C | | 52° | | | 52° | | | 52° | | |

†Full range is – 55°C to 125°C.

## PARAMETER MEASUREMENT INFORMATION

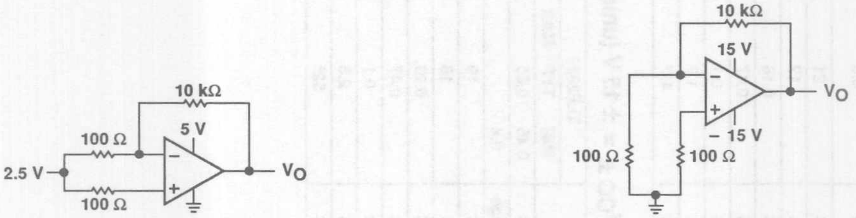


NOTE A: $C_L$ includes fixture capacitance.

(a) SINGLE-SUPPLY

(b) SPLIT-SUPPLY

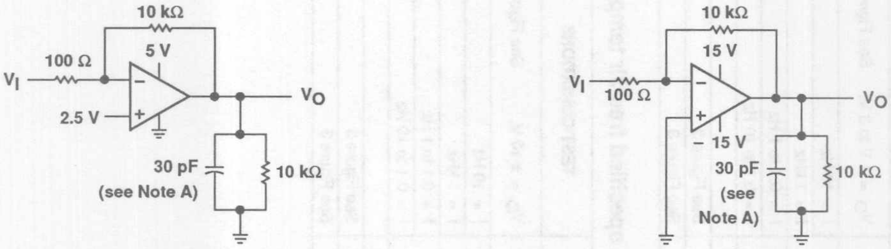
Figure 1. Slew Rate Test Circuit



(a) SINGLE-SUPPLY

(b) SPLIT-SUPPLY

Figure 2. Noise Voltage Test Circuit



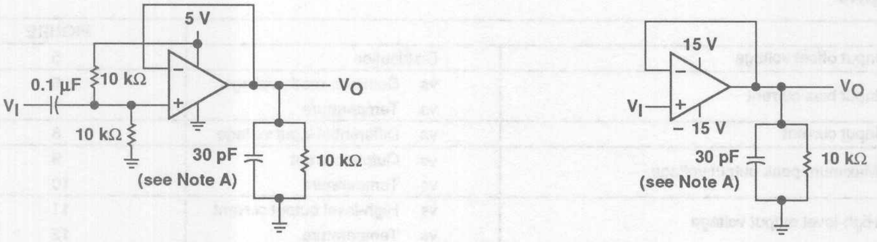
NOTE A: $C_L$ includes fixture capacitance.

(a) SINGLE-SUPPLY

(b) SPLIT-SUPPLY

Figure 3. Unity-Gain Bandwidth and Phase Margin Test Circuit

## PARAMETER MEASUREMENT INFORMATION



NOTE A: $C_L$ includes fixture capacitance.

(a) SINGLE-SUPPLY

(b) SPLIT-SUPPLY

Figure 4. Small-Signal Pulse Response Test Circuit

### typical values

Typical values as presented in this data sheet represent the median (50% point) of device parametric performance.

## TYPICAL CHARACTERISTICS

### table of graphs

| | | | FIGURE |
|---|---|---|---|
| $V_{IO}$ | Input offset voltage | Distribution | 5 |
| $I_{IB}$ | Input bias current | vs Common-mode voltage | 6 |
| | | vs Temperature | 7 |
| $I_I$ | Input current | vs Differential input voltage | 8 |
| $V_{OM}$ | Maximum peak output voltage | vs Output current | 9 |
| | | vs Temperature | 10 |
| $V_{OH}$ | High-level output voltage | vs High-level output current | 11 |
| | | vs Temperature | 12 |
| $V_{OL}$ | Low-level output voltage | vs Low-level output current | 13 |
| | | vs Temperature | 14 |
| $V_{O(PP)}$ | Maximum peak-to-peak output voltage swing | vs Frequency | 15, 16 |
| $A_{VD}$ | Differential voltage amplification | vs Frequency | 17 |
| | | vs Temperature | 18 |
| $I_{OS}$ | Short-circuit output current | vs Supply voltage | 19, 21 |
| | | vs Temperature | 20, 22 |
| $I_{CC}$ | Supply current | vs Supply voltage | 23 |
| | | vs Temperature | 24 |
| CMRR | Common-mode rejection ratio | vs Frequency | 25 |
| SR | Slew rate | vs Temperature | 26 |
| | Pulse response | Small-signal | 27, 28 |
| | | Large-signal | 29, 30 |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | 0.1 to 1 Hz | 31 |
| | | 0.1 to 10 Hz | 32 |
| $V_n$ | Equivalent input noise voltage | vs Frequency | 33 |
| $B_1$ | Unity-gain bandwidth | vs Supply voltage | 34 |
| | | vs Temperature | 35 |
| $\phi_m$ | Phase margin | vs Supply voltage | 36 |
| | | vs Capacitive load | 37 |
| | | vs Temperature | 38 |
| | Phase shift | vs Frequency | 17 |

## TYPICAL CHARACTERISTICS[†]

TLE2022
DISTRIBUTION OF
INPUT OFFSET VOLTAGE

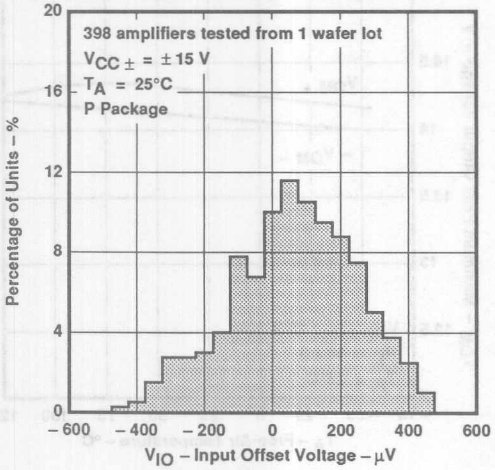


Figure 5

TLE2022
INPUT BIAS CURRENT
vs
COMMON-MODE INPUT VOLTAGE

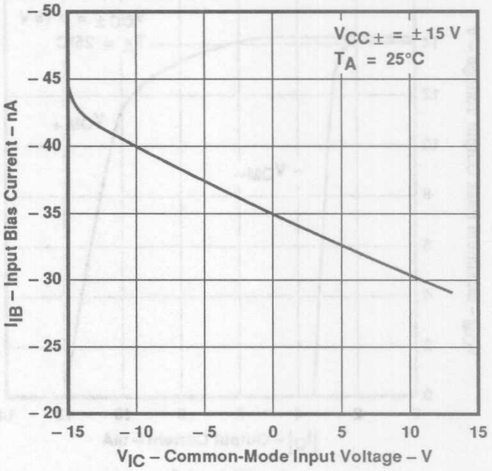


Figure 6

TLE2022
INPUT BIAS CURRENT
vs
FREE-AIR TEMPERATURE

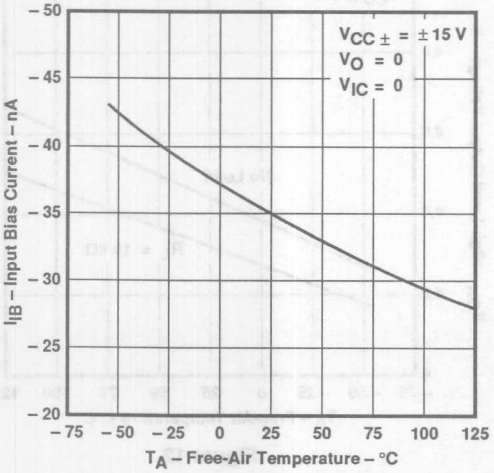


Figure 7

INPUT CURRENT
vs
DIFFERENTIAL INPUT VOLTAGE

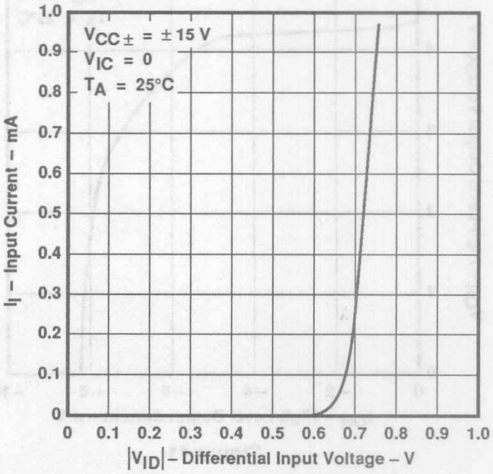


Figure 8

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[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS[†]

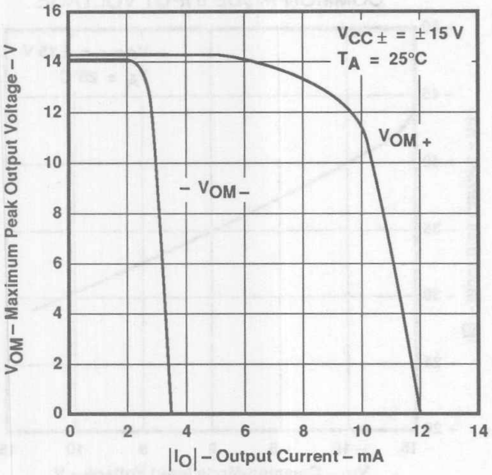
MAXIMUM PEAK OUTPUT VOLTAGE
vs
OUTPUT CURRENT

Figure 9

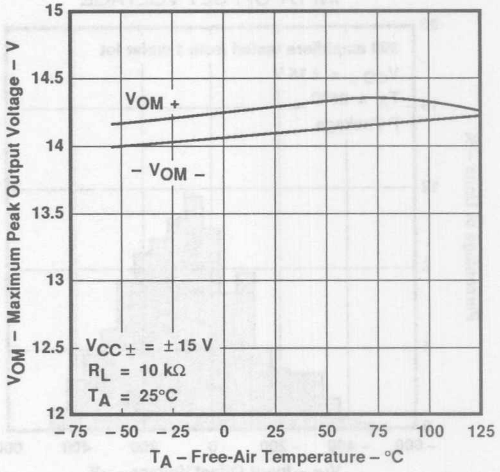
MAXIMUM PEAK OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE

Figure 10

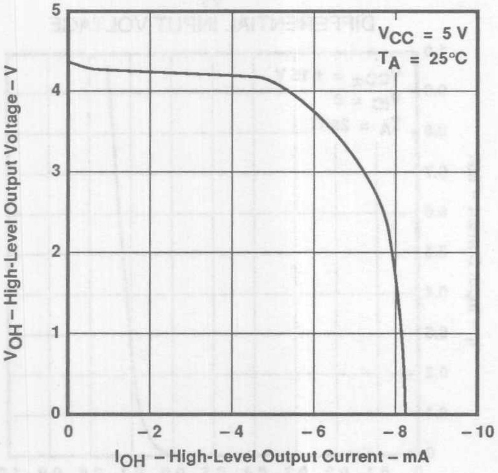
HIGH-LEVEL OUTPUT VOLTAGE
vs
HIGH-LEVEL OUTPUT CURRENT

Figure 11

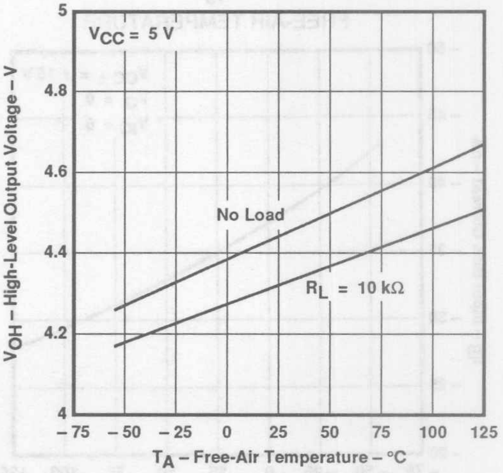
HIGH-LEVEL OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE

Figure 12

---

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS[†]

### LOW-LEVEL OUTPUT VOLTAGE vs LOW-LEVEL OUTPUT CURRENT

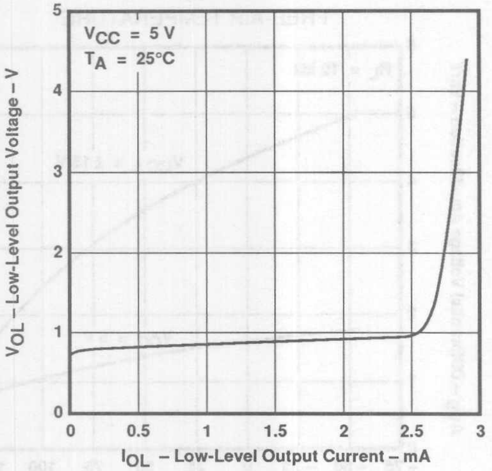

Figure 13

### LOW-LEVEL OUTPUT VOLTAGE vs FREE-AIR TEMPERATURE

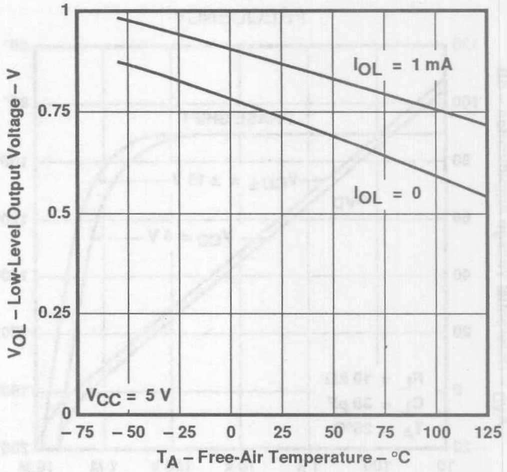

Figure 14

### MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE vs FREQUENCY

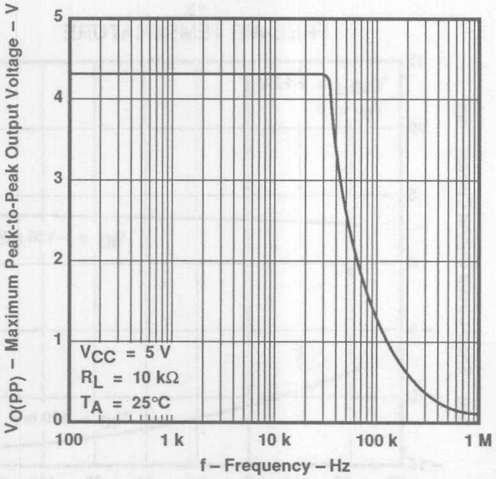

Figure 15

### MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE vs FREQUENCY

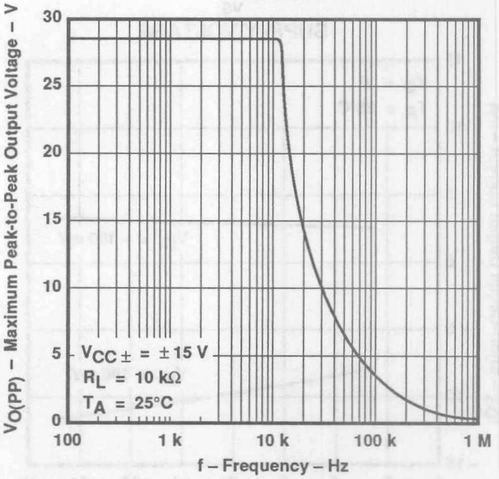

Figure 16

---

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

TLE2022
LARGE-SIGNAL DIFFERENTIAL VOLTAGE
AMPLIFICATION and PHASE SHIFT
vs
FREQUENCY

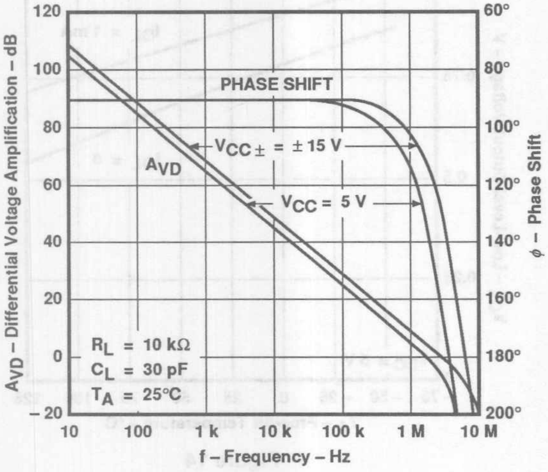

Figure 17

TLE2022
LARGE-SIGNAL DIFFERENTIAL VOLTAGE
AMPLIFICATION
vs
FREQUENCY
FREE-AIR TEMPERATURE

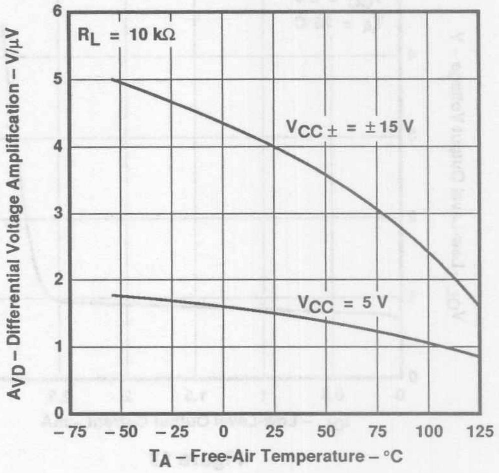

Figure 18

SHORT-CIRCUIT OUTPUT CURRENT
vs
SUPPLY VOLTAGE

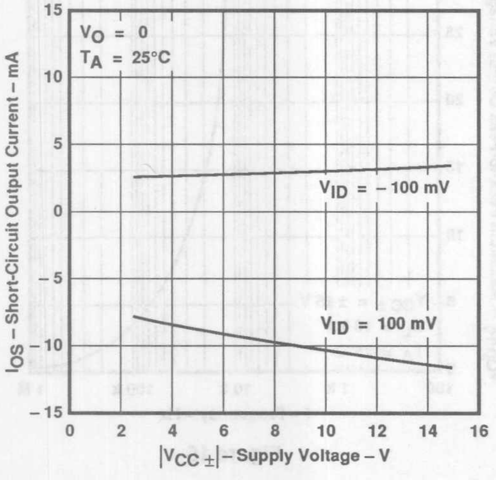

Figure 19

SHORT-CIRCUIT OUTPUT CURRENT
vs
FREE-AIR TEMPERATURE

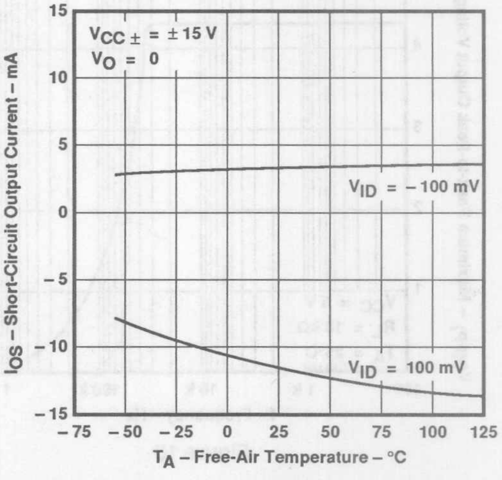

Figure 20

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†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS[†]

SHORT-CIRCUIT OUTPUT CURRENT
vs
SUPPLY VOLTAGE

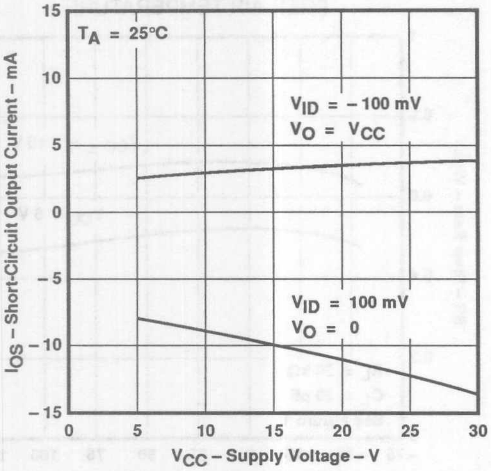


Figure 21

SHORT-CIRCUIT OUTPUT CURRENT
vs
FREE-AIR TEMPERATURE

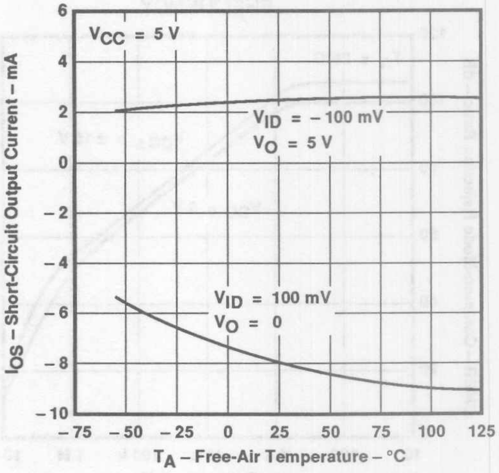


Figure 22

SUPPLY CURRENT
vs
SUPPLY VOLTAGE

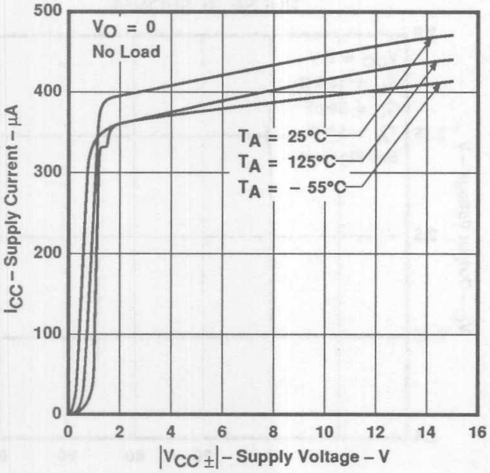


Figure 23

SUPPLY CURRENT
vs
FREE-AIR TEMPERATURE

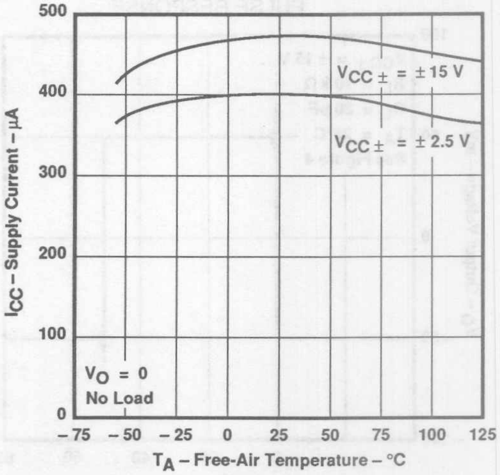


Figure 24

---

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

TLE2022
COMMON-MODE REJECTION RATIO
vs
FREQUENCY

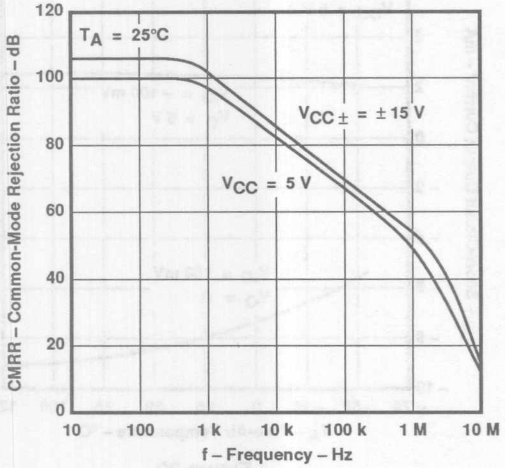


Figure 25

SLEW RATE
vs
FREE-AIR TEMPERATURE

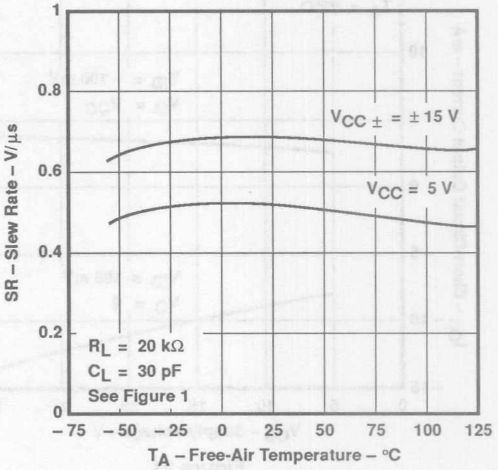


Figure 26

VOLTAGE-FOLLOWER
SMALL-SIGNAL
PULSE RESPONSE

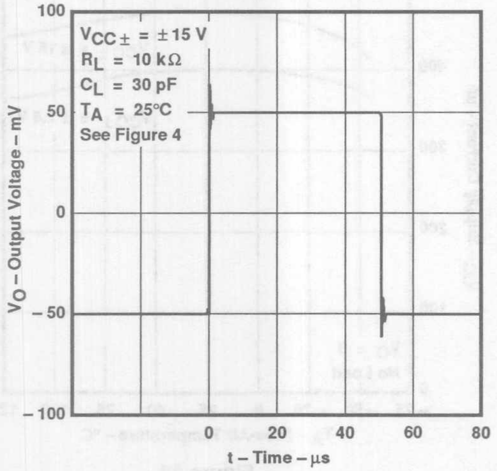


Figure 27

VOLTAGE-FOLLOWER
SMALL-SIGNAL
PULSE RESPONSE

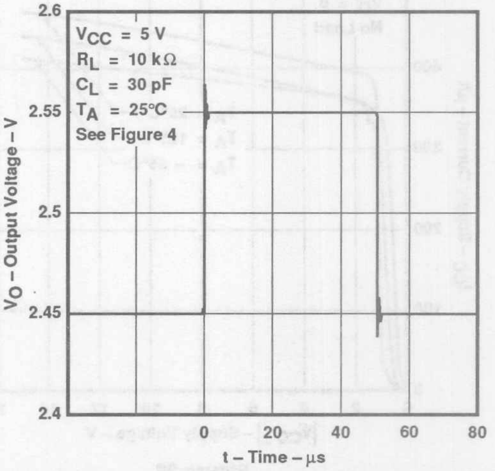


Figure 28

---

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS

VOLTAGE-FOLLOWER
LARGE-SIGNAL
PULSE RESPONSE

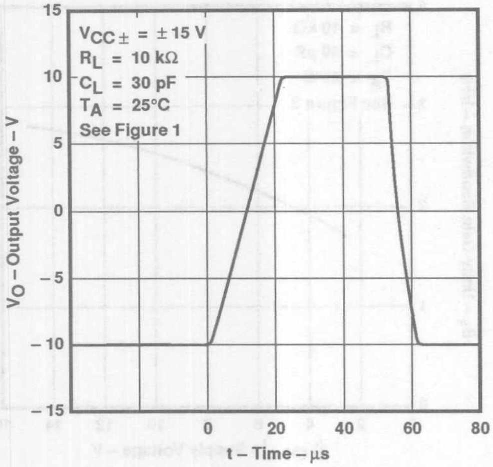


Figure 29

VOLTAGE-FOLLOWER
LARGE-SIGNAL
PULSE RESPONSE

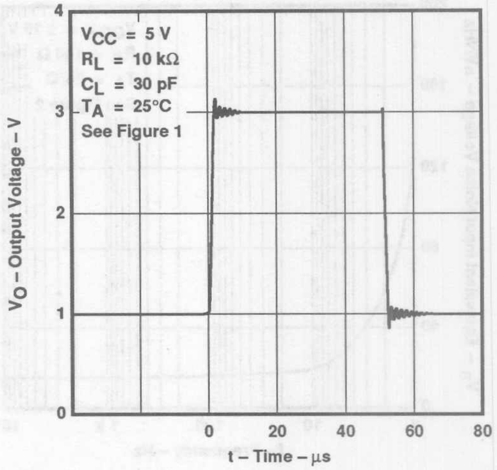


Figure 30

PEAK-TO-PEAK EQUIVALENT
INPUT NOISE VOLTAGE
0.1 TO 1 Hz

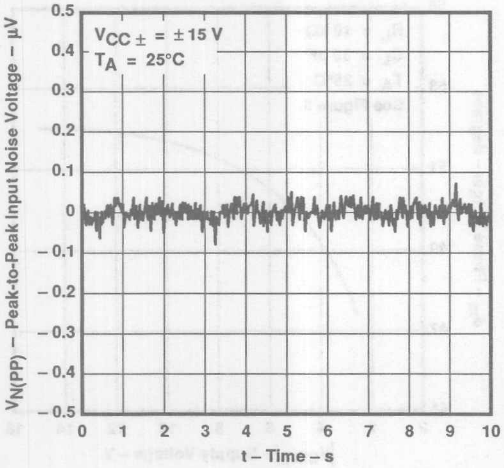


Figure 31

PEAK-TO-PEAK EQUIVALENT
INPUT NOISE VOLTAGE
0.1 TO 10 Hz

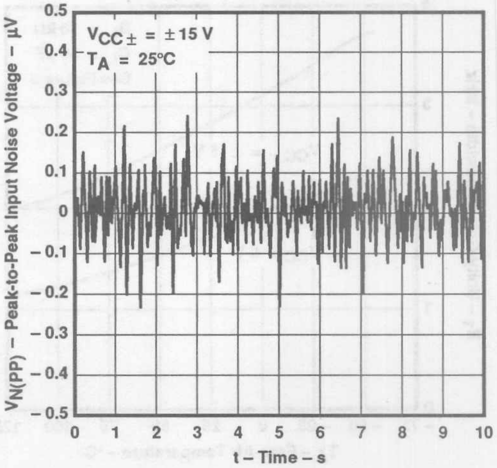
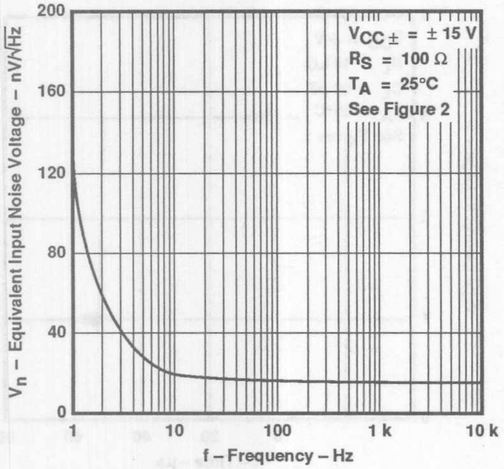


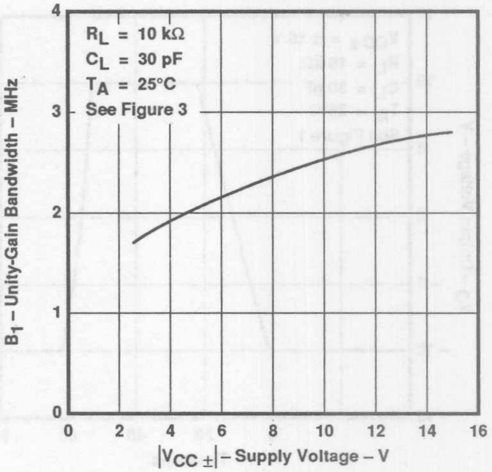
Figure 32

## TYPICAL CHARACTERISTICS†



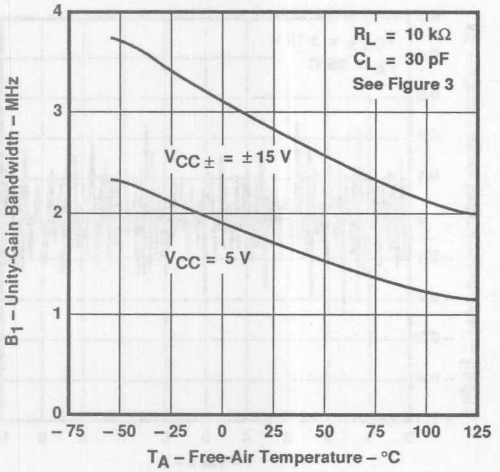
EQUIVALENT INPUT NOISE VOLTAGE
vs
FREQUENCY

Figure 33



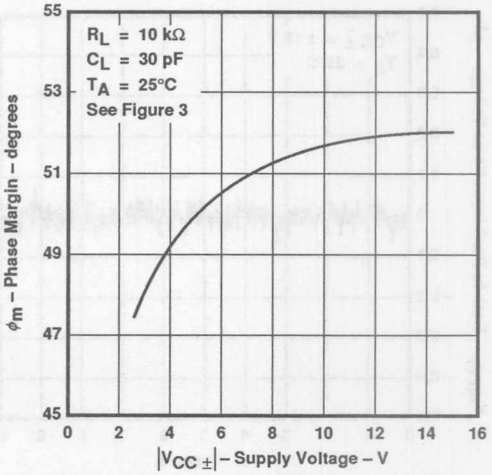
UNITY-GAIN BANDWIDTH
vs
SUPPLY VOLTAGE

Figure 34



UNITY-GAIN BANDWIDTH
vs
FREE-AIR TEMPERATURE

Figure 35



PHASE MARGIN
vs
SUPPLY VOLTAGE

Figure 36

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† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS[†]

PHASE MARGIN
vs
LOAD CAPACITANCE

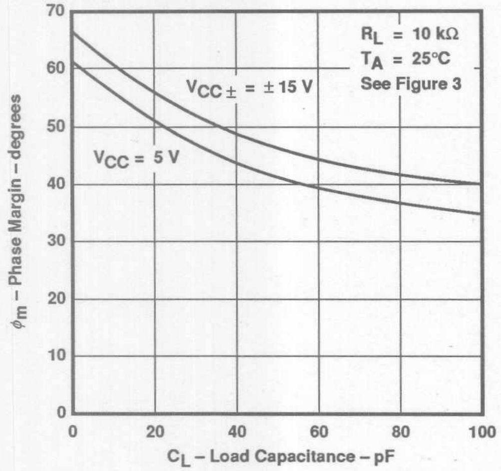

Figure 37

PHASE MARGIN
vs
FREE-AIR TEMPERATURE

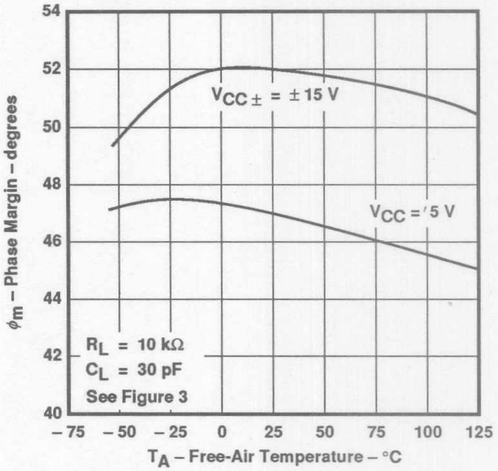

Figure 38

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[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## APPLICATION INFORMATION

### voltage-follower applications

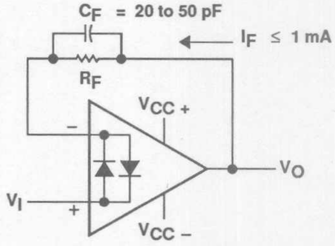


**Figure 39. Voltage Follower**

The TLE2022 circuitry includes input protection diodes to limit the voltage across the input transistors; however, no provision is made in the circuit to limit the current if these diodes are forward-biased. Note that this condition can occur when the device is operated in the voltage-follower configuration and driven with a fast, large-signal pulse. It is recommended that a feedback resistor be used to limit the current to a maximum of 1 mA to prevent degradation of the device. Also, remember that this feedback resistor will form a pole with the input capacitance of the device. For feedback resistor values greater than 10 kΩ, this pole will degrade the amplifier's phase margin. This problem can be alleviated by adding a capacitor (20 pF to 50 pF) in parallel with the feedback resistor (see Figure 39).

### input characteristics

The input of any unused amplifiers should be tied to ground to avoid possible oscillation.

# TLE2024, TLE2024A, TLE2024B
# EXCALIBUR HIGH-SPEED LOW-POWER PRECISION QUAD OPERATIONAL AMPLIFIERS

D3265, MAY 1989 – REVISED FEBRUARY 1991

## available features

- **Supply Current . . . 1 mA Max**
- **High Unity-Gain Bandwidth . . . 2.8 MHz Typ**
- **High Slew Rate . . . 0.45 V/µs Min**
- **Supply Current Change Over Military Temp Range . . . 50 µA Typ**
- **Specified for Both 5 V/Gnd and ± 15 V Operation**
- **Phase-Reversal Protection**
- **High Open-Loop Gain . . . 7 V/µV (137 dB) Typ**
- **Low Offset Voltage . . . 500 µV Max**
- **Offset Voltage Drift With Time . . . 0.005 µV/mo Typ**
- **Low Input Bias Current . . . 50 nA Max**
- **Low Noise Voltage . . . 19 nV/√Hz Typ at f = 10 Hz**

## description

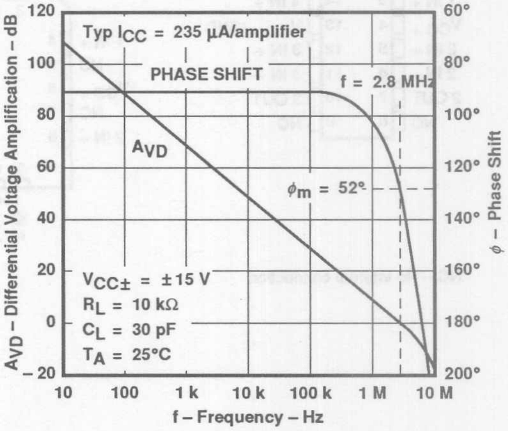
The TLE2024, TLE2024A, and TLE2024B devices are precision, high-speed, low-power operational amplifiers using Texas Instruments patent-pending Excalibur process. These devices combine the best features of the OP421 with highly improved slew rate, unity-gain bandwidth, and input offset voltage.

The complementary bipolar Excalibur process utilizes isolated vertical P-N-P transistors that yield dramatic improvement in unity-gain bandwidth and slew rate over similar devices.

The addition of a patent-pending bias circuit in conjunction with this process results in extremely stable parameters with both time and temperature. This means that a "precision" device remains a precision device even with changes in temperature and over years of use.

This combination of excellent dc performance with a common-mode input voltage range that

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION and PHASE SHIFT vs FREQUENCY



### AVAILABLE OPTIONS

| $T_A$ | $V_{IO}$ max AT 25°C | PACKAGE | | | |
|---|---|---|---|---|---|
| | | SMALL-OUTLINE (DW) | CHIP CARRIER (FK) | CERAMIC DIP (J) | PLASTIC DIP (N) |
| 0°C<br>to<br>70°C | 500 µV<br>750 µV<br>1000 µV | TLE2024BCDW<br>TLE2024ACDW<br>TLE2024CDW | —<br>—<br>— | —<br>—<br>— | TLE2024BCN<br>TLE2024ACN<br>TLE2024CN |
| – 40°C<br>to<br>85°C | 500 µV<br>750 µV<br>1000 µV | TLE2024BIDW<br>TLE2024AIDW<br>TLE2024IDW | —<br>—<br>— | —<br>—<br>— | TLE2024BIN<br>TLE2024AIN<br>TLE2024IN |
| – 55°C<br>to<br>125°C | 500 µV<br>750 µV<br>1000 µV | TLE2024BMDW<br>TLE2024AMDW<br>TLE2024MDW | —<br>TLE2024AMFK<br>TLE2024MFK | TLE2024BMJ<br>TLE2024AMJ<br>TLE2024MJ | TLE2024BMN<br>TLE2024AMN<br>TLE2024MN |

D packages are available taped and reeled. Add "R" suffix to device type (e.g.,TLE2024BCDWR).

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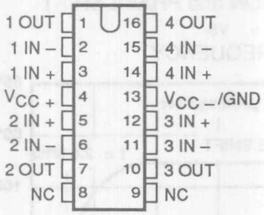
## description (continued)

includes the negative rail makes these devices the ideal choice for low-level signal conditioning applications in either single-supply or split-supply configurations. In addition, these devices offer phase-reversal protection circuitry that eliminates an unexpected change in output states when one of the inputs goes below the negative supply rail.

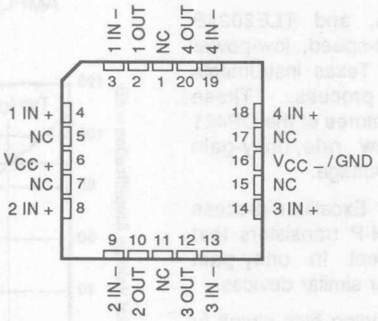
A variety of available packaging options includes small-outline and chip carrier versions for high-density systems applications.

The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from −40°C to 85°C. The M-suffix devices are characterized for operation over the full military temperature range of −55°C to 125°C.

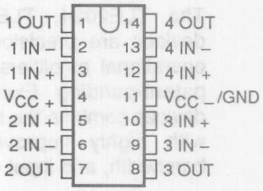
**DW PACKAGE**
**(TOP VIEW)**



**FK PACKAGE**
**(TOP VIEW)**

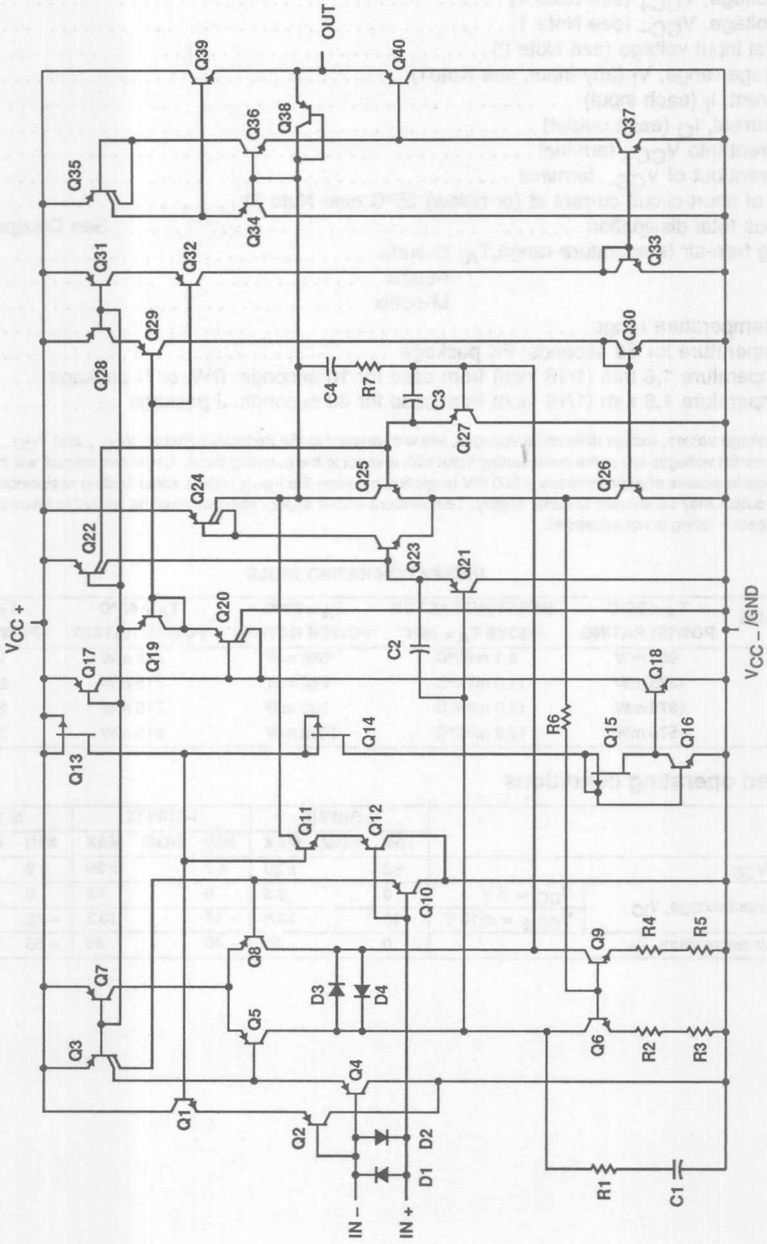


**J or N PACKAGE**
**(TOP VIEW)**



NC – No internal connection

### equivalent schematic (each amplifier)



## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | | |
|---|---|---|
| Supply voltage, $V_{CC+}$ (see Note 1) | | 20 V |
| Supply voltage, $V_{CC-}$ (see Note 1) | | −20 V |
| Differential input voltage (see Note 2) | | ±0.6 V |
| Input voltage range, $V_I$ (any input, see Note1) | | $V_{CC\pm}$ |
| Input current, $I_I$ (each input) | | ±1 mA |
| Output current, $I_O$ (each output) | | ±40 mA |
| Total current into $V_{CC+}$ terminal | | 80 mA |
| Total current out of $V_{CC-}$ terminal | | 80 mA |
| Duration of short-circuit current at (or below) 25°C (see Note 3) | | unlimited |
| Continuous total dissipation | | See Dissipation Rating Table |
| Operating free-air temperature range, $T_A$: | C-suffix | 0°C to 70°C |
| | I-suffix | −40°C to 85°C |
| | M-suffix | −55°C to 125°C |
| Storage temperature range | | −65°C to 150°C |
| Case temperature for 60 seconds: FK package | | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: DW, or N package | | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package | | 300°C |

NOTES:
1. All voltage values, except differential voltages, are with respect to the midpoint between $V_{CC+}$ and $V_{CC-}$.
2. Differential voltages are at the noninverting input with respect to the inverting input. Excessive current will flow if a differential input voltage in excess of approximately ± 600 mV is applied between the inputs unless some limiting resistance is used.
3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

**DISSIPATION RATING TABLE**

| PACKAGE | $T_A \leq 25°C$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25°C$ | $T_A = 70°C$ POWER RATING | $T_A = 85°C$ POWER RATING | $T_A = 125°C$ POWER RATING |
|---|---|---|---|---|---|
| DW | 950 mW | 8.1 mW/°C | 586 mW | 464 mW | 140 mW |
| FK | 1375 mW | 11.0 mW/°C | 880 mW | 715 mW | 275 mW |
| J | 1375 mW | 11.0 mW/°C | 880 mW | 715 mW | 275 mW |
| N | 1575 mW | 12.6 mW/°C | 1008 mW | 819 mW | 315 mW |

## recommended operating conditions

| | | C-SUFFIX | | | I-SUFFIX | | | M-SUFFIX | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MIN | NOM | MAX | MIN | NOM | MAX | MIN | NOM | MAX | |
| Supply voltage, $V_{CC}$ | | ± 2 | | ± 20 | ± 2 | | ± 20 | ± 2 | | ± 20 | V |
| Common-mode input voltage, $V_{IC}$ | $V_{CC} = 5$ V | 0 | | 3.5 | 0 | | 3.2 | 0 | | 3.2 | V |
| | $V_{CC\pm} = \pm 15$ V | − 15 | | 13.5 | − 15 | | 13.2 | − 15 | | 13.2 | |
| Operating free-air temperature, $T_A$ | | 0 | | 70 | − 40 | | 85 | − 55 | | 125 | °C |

## electrical characteristics at specified free-air temperature, $V_{CC}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TLE2024 | | | TLE2024A | | | TLE2024B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC}$ = 0, | $R_S$ = 50 Ω | 25°C | | | 1100 | | | 850 | | | 600 | µV |
| | | | | Full range | | | 1300 | | | 1050 | | | 800 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 2 | | | 2 | | | 2 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.005 | | | 0.005 | | | 0.005 | | µV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 0.6 | 6 | | 0.5 | 5 | | 0.4 | 4 | nA |
| | | | | Full range | | | 6 | | | 5 | | | 4 | |
| $I_{IB}$ | Input bias current | | | 25°C | | 45 | 60 | | 40 | 55 | | 35 | 50 | nA |
| | | | | Full range | | | 65 | | | 60 | | | 55 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S$ = 50 Ω | | 25°C | 0<br>to<br>3.5 | −0.3<br>to<br>4 | | 0<br>to<br>3.5 | −0.3<br>to<br>4 | | 0<br>to<br>3.5 | −0.3<br>to<br>4 | | V |
| | | | | Full range | 0<br>to<br>3.5 | | | 0<br>to<br>3.5 | | | 0<br>to<br>3.5 | | | |
| $V_{OH}$ | High-level output voltage | $R_L$ = 10 kΩ | | 25°C | 3.9 | 4.2 | | 3.9 | 4.2 | | 4 | 4.3 | | V |
| | | | | Full range | 3.7 | | | 3.7 | | | 3.8 | | | |
| $V_{OL}$ | Low-level output voltage | | | 25°C | | 0.7 | 0.8 | | 0.7 | 0.8 | | 0.7 | 0.8 | V |
| | | | | Full range | | | 0.95 | | | 0.95 | | | 0.95 | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O$ = 1.4 V to 4 V, | $R_L$ = 10 kΩ | 25°C | 0.2 | 1.5 | | 0.3 | 1.5 | | 0.4 | 1.5 | | V/µV |
| | | | | Full range | 0.1 | | | 0.1 | | | 0.1 | | | |
| CMRR | Common-mode rejection ratio | $V_{IC}$ = $V_{ICR}$ min, | $R_S$ = 50 Ω | 25°C | 80 | 90 | | 82 | 92 | | 85 | 95 | | dB |
| | | | | Full range | 80 | | | 82 | | | 85 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC} / \Delta V_{IO}$) | $V_{CC}$ = 5 V to 30 V | | 25°C | 98 | 112 | | 100 | 115 | | 103 | 117 | | dB |
| | | | | Full range | 93 | | | 95 | | | 98 | | | |
| $I_{CC}$ | Supply current | $V_O$ = 2.5 V, | No load | 25°C | | 700 | 1000 | | 700 | 1000 | | 700 | 1000 | µA |
| | | | | Full range | | | 1000 | | | 1000 | | | 1000 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | | Full range | | 15 | | | 15 | | | 15 | | µA |

† Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A$ = 150°C extrapolated to $T_A$ = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2024 | | | TLE2024A | | | TLE2024B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | | 1000 | | | 750 | | | 500 | µV |
| | | | Full range | | | 1200 | | | 950 | | | 700 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 2 | | | 2 | | | 2 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.006 | | | 0.006 | | | 0.006 | | µV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 0.6 | 6 | | 0.5 | 5 | | 0.4 | 4 | nA |
| | | | Full range | | | 6 | | | 5 | | | 4 | |
| $I_{IB}$ | Input bias current | | 25°C | | 50 | 60 | | 45 | 55 | | 40 | 50 | nA |
| | | | Full range | | | 65 | | | 60 | | | 55 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | 25°C | − 15 to 13.5 | − 15.3 to 14 | | − 15 to 13.5 | − 15.3 to 14 | | − 15 to 13.5 | − 15.3 to 14 | | V |
| | | | Full range | − 15 to 13.5 | | | − 15 to 13.5 | | | − 15 to 13.5 | | | |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $R_L = 10\ k\Omega$ | 25°C | 13.8 | 14.1 | | 13.9 | 14.2 | | 14 | 14.3 | | V |
| | | | Full range | 13.7 | | | 13.8 | | | 13.9 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | 25°C | − 13.7 | − 14.1 | | − 13.7 | − 14.1 | | − 13.7 | − 14.1 | | V |
| | | | Full range | − 13.6 | | | − 13.6 | | | − 13.6 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = \pm 10$ V, $R_L = 10\ k\Omega$ | 25°C | 0.4 | 2 | | 0.8 | 4 | | 1 | 7 | | V/µV |
| | | | Full range | 0.4 | | | 0.8 | | | 1 | | | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 25°C | 92 | 102 | | 94 | 105 | | 97 | 108 | | dB |
| | | | Full range | 88 | | | 90 | | | 93 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 2.5$ V to $\pm 15$ V | 25°C | 98 | 112 | | 100 | 115 | | 103 | 117 | | dB |
| | | | Full range | 93 | | | 95 | | | 98 | | | |
| $I_{CC}$ | Supply current | $V_O = 0$, No load | 25°C | | 940 | 1200 | | 940 | 1200 | | 940 | 1200 | µA |
| | | | Full range | | | 1200 | | | 1200 | | | 1200 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | Full range | | 20 | | | 20 | | | 20 | | µA |

† Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$ | TLE2024 | | | TLE2024A | | | TLE2024B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O$ = 1 V to 3 V, See Figure 1 | 25°C | | 0.5 | | | 0.5 | | | 0.5 | | V/μs |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz | 25°C | | 21 | 50 | | 21 | 50 | | 21 | 50 | $\mathrm{nV}/\sqrt{\mathrm{Hz}}$ |
| | | f = 1 kHz | 25°C | | 17 | 30 | | 17 | 30 | | 17 | 30 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.16 | | | 0.16 | | | 0.16 | | μV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.47 | | | 0.47 | | | 0.47 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.1 | | | 0.1 | | | 0.1 | | $\mathrm{pA}/\sqrt{\mathrm{Hz}}$ |
| $B_1$ | Unity-gain bandwidth | See Figure 3 | 25°C | | 1.7 | | | 1.7 | | | 1.7 | | MHz |
| $\phi_m$ | Phase margin at unity gain | See Figure 3 | 25°C | | 47° | | | 47° | | | 47° | | |

## operating characteristics at specified free-air temperature, $V_{CC\pm}$ = ± 15 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2024 | | | TLE2024A | | | TLE2024B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O$ = ± 10 V, See Figure 1 | 25°C | 0.45 | 0.7 | | 0.45 | 0.7 | | 0.45 | 0.7 | | V/μs |
| | | | Full range | 0.45 | | | 0.45 | | | 0.45 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz | 25°C | | 19 | 50 | | 19 | 50 | | 19 | 50 | $\mathrm{nV}/\sqrt{\mathrm{Hz}}$ |
| | | f = 1 kHz | 25°C | | 15 | 30 | | 15 | 30 | | 15 | 30 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.16 | | | 0.16 | | | 0.16 | | μV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.47 | | | 0.47 | | | 0.47 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.1 | | | 0.1 | | | 0.1 | | $\mathrm{pA}/\sqrt{\mathrm{Hz}}$ |
| $B_1$ | Unity-gain bandwidth | See Figure 3 | 25°C | | 2.8 | | | 2.8 | | | 2.8 | | MHz |
| $\phi_m$ | Phase margin at unity gain | See Figure 3 | 25°C | | 52° | | | 52° | | | 52° | | |

† Full range is 0°C to 70°C.

## electrical characteristics at specified free-air temperature, $V_{CC}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TLE2024 | | | TLE2024A | | | TLE2022B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC}$ = 0, | $R_S$ = 50 Ω | 25°C | | | 1100 | | | 850 | | | 600 | µV |
| | | | | Full range | | | 1300 | | | 1050 | | | 800 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 2 | | | 2 | | | 2 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.005 | | | 0.005 | | | 0.005 | | µV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 0.6 | 6 | | 0.5 | 5 | | 0.4 | 4 | nA |
| | | | | Full range | | | 7 | | | 6 | | | 5 | |
| $I_{IB}$ | Input bias current | | | 25°C | | 45 | 60 | | 40 | 55 | | 35 | 50 | nA |
| | | | | Full range | | | 70 | | | 65 | | | 60 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S$ = 50 Ω | | 25°C | 0<br>to<br>3.5 | − 0.3<br>to<br>4 | | 0<br>to<br>3.5 | − 0.3<br>to<br>4 | | 0<br>to<br>3.5 | − 0.3<br>to<br>4 | | V |
| | | | | Full range | 0<br>to<br>3.2 | | | 0<br>to<br>3.2 | | | 0<br>to<br>3.2 | | | |
| $V_{OH}$ | High-level output voltage | $R_L$ = 10 kΩ | | 25°C | 3.9 | 4.2 | | 3.9 | 4.2 | | 4 | 4.3 | | V |
| | | | | Full range | 3.7 | | | 3.7 | | | 3.8 | | | |
| $V_{OL}$ | Low-level output voltage | | | 25°C | | 0.7 | 0.8 | | 0.7 | 0.8 | | 0.7 | 0.8 | V |
| | | | | Full range | | | 0.95 | | | 0.95 | | | 0.95 | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O$ = 1.4 V to 4 V, | $R_L$ = 10 kΩ | 25°C | 0.2 | 1.5 | | 0.3 | 1.5 | | 0.4 | 1.5 | | V/µV |
| | | | | Full range | 0.1 | | | 0.1 | | | 0.1 | | | |
| CMRR | Common-mode rejection ratio | $V_{IC}$ = $V_{ICR}$ min, | $R_S$ = 50 Ω | 25°C | 80 | 90 | | 82 | 92 | | 85 | 95 | | dB |
| | | | | Full range | 80 | | | 82 | | | 85 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC}$ = 5 V to 30 V | | 25°C | 98 | 112 | | 100 | 115 | | 103 | 117 | | dB |
| | | | | Full range | 93 | | | 95 | | | 98 | | | |
| $I_{CC}$ | Supply current | $V_O$ = 2.5 V, | No load | 25°C | | 700 | 1000 | | 700 | 1000 | | 700 | 1000 | µA |
| | | | | Full range | | | 1000 | | | 1000 | | | 1000 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | | Full range | | 30 | | | 30 | | | 30 | | µA |

†Full range is – 40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A$ = 150°C extrapolated to $T_A$ = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TLE2024 | | | TLE2024A | | | TLE2024B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC} = 0$, | $R_S = 50\ \Omega$ | 25°C | | | 1000 | | | 750 | | | 500 | µV |
| | | | | Full range | | | 1200 | | | 950 | | | 700 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 2 | | | 2 | | | 2 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.006 | | | 0.006 | | | 0.006 | | µV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 0.6 | 6 | | 0.5 | 5 | | 0.4 | 4 | nA |
| | | | | Full range | | | 7 | | | 6 | | | 5 | |
| $I_{IB}$ | Input bias current | | | 25°C | | 50 | 60 | | 45 | 55 | | 40 | 50 | nA |
| | | | | Full range | | | 70 | | | 65 | | | 60 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | | 25°C | − 15<br>to<br>13.5 | − 15.3<br>to<br>14 | | − 15<br>to<br>13.5 | − 15.3<br>to<br>14 | | − 15<br>to<br>13.5 | − 15.3<br>to<br>14 | | V |
| | | | | Full range | − 15<br>to<br>13.2 | | | − 15<br>to<br>13.2 | | | − 15<br>to<br>13.2 | | | |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $R_L = 10\ k\Omega$ | | 25°C | 13.8 | 14.1 | | 13.9 | 14.2 | | 14 | 14.3 | | V |
| | | | | Full range | 13.7 | | | 13.7 | | | 13.8 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | | 25°C | − 13.7 | − 14.1 | | − 13.7 | − 14.1 | | − 13.7 | − 14.1 | | V |
| | | | | Full range | − 13.6 | | | − 13.6 | | | − 13.6 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = \pm 10$ V, | $R_L = 10\ k\Omega$ | 25°C | 0.4 | 2 | | 0.8 | 4 | | 1 | 7 | | V/µV |
| | | | | Full range | 0.4 | | | 0.8 | | | 1 | | | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min, | $R_S = 50\ \Omega$ | 25°C | 92 | 102 | | 94 | 105 | | 97 | 108 | | dB |
| | | | | Full range | 88 | | | 90 | | | 93 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 2.5$ V to ± 15 V | | 25°C | 98 | 112 | | 100 | 115 | | 103 | 117 | | dB |
| | | | | Full range | 93 | | | 95 | | | 98 | | | |
| $I_{CC}$ | Supply current | $V_O = 0$, | No load | 25°C | | 940 | 1200 | | 940 | 1200 | | 940 | 1200 | µA |
| | | | | Full range | | | 1200 | | | 1200 | | | 1200 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | | Full range | | 50 | | | 50 | | | 50 | | µA |

† Full range is − 40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

### operating characteristics at specified free-air temperature, $V_{CC}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$ | TLE2024 | | | TLE2024A | | | TLE2024B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O$ = 1 V to 3 V, See Figure 1 | 25°C | | 0.5 | | | 0.5 | | | 0.5 | | V/μs |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz | 25°C | | 21 | 50 | | 21 | 50 | | 21 | 50 | nV/√Hz |
| | | f = 1 kHz | 25°C | | 17 | 30 | | 17 | 30 | | 17 | 30 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.16 | | | 0.16 | | | 0.16 | | μV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.47 | | | 0.47 | | | 0.47 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.1 | | | 0.1 | | | 0.1 | | pA/√Hz |
| $B_1$ | Unity-gain bandwidth | See Figure 3 | 25°C | | 1.7 | | | 1.7 | | | 1.7 | | MHz |
| $\phi_m$ | Phase margin at unity gain | See Figure 3 | 25°C | | 47° | | | 47° | | | 47° | | |

### operating characteristics at specified free-air temperature, $V_{CC}$ ± = ± 15 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2024 | | | TLE2024A | | | TLE2024B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O$ = ± 10 V, See Figure 1 | 25°C | 0.45 | 0.7 | | 0.45 | 0.7 | | 0.45 | 0.7 | | V/μs |
| | | | Full range | 0.42 | | | 0.42 | | | 0.42 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz | 25°C | | 19 | 50 | | 19 | 50 | | 19 | 50 | nV/√Hz |
| | | f = 1 kHz | 25°C | | 15 | 30 | | 15 | 30 | | 15 | 30 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.16 | | | 0.16 | | | 0.16 | | μV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.47 | | | 0.47 | | | 0.47 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.1 | | | 0.1 | | | 0.1 | | pA/√Hz |
| $B_1$ | Unity-gain bandwidth | See Figure 3 | 25°C | | 2.8 | | | 2.8 | | | 2.8 | | MHz |
| $\phi_m$ | Phase margin at unity gain | See Figure 3 | 25°C | | 52° | | | 52° | | | 52° | | |

†Full range is – 40°C to 85°C.

## electrical characteristics at specified free-air temperature, $V_{CC}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2024 | | | TLE2024A | | | TLE2024B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC}$ = 0, $R_S$ = 50 Ω | 25°C | | | 1100 | | | 850 | | | 600 | µV |
| | | | Full range | | | 1300 | | | 1050 | | | 800 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 2 | | | 2 | | | 2 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.005 | | | 0.005 | | | 0.005 | | µV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 0.6 | 6 | | 0.5 | 5 | | 0.4 | 4 | nA |
| | | | Full range | | | 10 | | | 9 | | | 8 | |
| $I_{IB}$ | Input bias current | | 25°C | | 45 | 60 | | 40 | 55 | | 35 | 50 | nA |
| | | | Full range | | | 80 | | | 75 | | | 70 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S$ = 50 Ω | 25°C | 0 to 3.5 | − 0.3 to 4 | | 0 to 3.5 | − 0.3 to 4 | | 0 to 3.5 | − 0.3 to 4 | | V |
| | | | Full range | 0 to 3.2 | | | 0 to 3.2 | | | 0 to 3.2 | | | |
| $V_{OH}$ | High-level output voltage | $R_L$ = 10 kΩ | 25°C | 3.9 | 4.2 | | 3.9 | 4.2 | | 4 | 4.3 | | V |
| | | | Full range | 3.7 | | | 3.7 | | | 3.8 | | | |
| $V_{OL}$ | Low-level output voltage | | 25°C | | 0.7 | 0.8 | | 0.7 | 0.8 | | 0.7 | 0.8 | V |
| | | | Full range | | | 0.95 | | | 0.95 | | | 0.95 | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O$ = 1.4 V to 4 V, $R_L$ = 10 kΩ | 25°C | 0.2 | 1.5 | | 0.3 | 1.5 | | 0.4 | 1.5 | | V/µV |
| | | | Full range | 0.1 | | | 0.1 | | | 0.1 | | | |
| CMRR | Common-mode rejection ratio | $V_{IC}$ = $V_{ICR}$ min, $R_S$ = 50 Ω | 25°C | 80 | 90 | | 82 | 92 | | 85 | 95 | | dB |
| | | | Full range | 80 | | | 82 | | | 85 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC}$ / $\Delta V_{IO}$) | $V_{CC}$ = 5 V to 30 V | 25°C | 98 | 112 | | 100 | 115 | | 103 | 117 | | dB |
| | | | Full range | 93 | | | 95 | | | 98 | | | |
| $I_{CC}$ | Supply current | $V_O$ = 2.5 V, No load | 25°C | | 700 | 1000 | | 700 | 1000 | | 700 | 1000 | µA |
| | | | Full range | | | 1000 | | | 1000 | | | 1000 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature | | Full range | | 50 | | | 50 | | | 50 | | µA |

† Full range is − 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A$ = 150°C extrapolated to $T_A$ = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2024 | | | TLE2024A | | | TLE2024B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | | 1000 | | | 750 | | | 500 | µV |
| | | | Full range | | | 1200 | | | 950 | | | 700 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 2 | | | 2 | | | 2 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.006 | | | 0.006 | | | 0.006 | | µV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 0.6 | 6 | | 0.5 | 5 | | 0.4 | 4 | nA |
| | | | Full range | | | 10 | | | 9 | | | 8 | |
| $I_{IB}$ | Input bias current | | 25°C | | 50 | 60 | | 45 | 55 | | 40 | 50 | nA |
| | | | Full range | | | 80 | | | 75 | | | 70 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | 25°C | −15 to 13.5 | −15.3 to 14 | | −15 to 13.5 | −15.3 to 14 | | −15 to 13.5 | −15.3 to 14 | | V |
| | | | Full range | −15 to 13.2 | | | −15 to 13.2 | | | −15 to 13.2 | | | |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $R_L = 10\ k\Omega$ | 25°C | 13.8 | 14.1 | | 13.9 | 14.2 | | 14 | 14.3 | | V |
| | | | Full range | 13.7 | | | 13.7 | | | 13.8 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | 25°C | −13.7 | −14.1 | | −13.7 | −14.1 | | −13.7 | −14.1 | | V |
| | | | Full range | −13.6 | | | −13.6 | | | −13.6 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = \pm 10$ V, $R_L = 10\ k\Omega$ | 25°C | 0.4 | 2 | | 0.8 | 4 | | 1 | 7 | | V/µV |
| | | | Full range | 0.4 | | | 0.8 | | | 1 | | | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 25°C | 92 | 102 | | 94 | 105 | | 97 | 108 | | dB |
| | | | Full range | 88 | | | 90 | | | 93 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 2.5$ V to $\pm 15$ V | 25°C | 98 | 112 | | 100 | 115 | | 103 | 117 | | dB |
| | | | Full range | 93 | | | 95 | | | 98 | | | |
| $I_{CC}$ | Supply current | $V_O = 0$, No load | 25°C | | 940 | 1200 | | 940 | 1200 | | 940 | 1200 | µA |
| | | | Full range | | | 1200 | | | 1200 | | | 1200 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | Full range | | 85 | | | 85 | | | 85 | | µA |

† Full range is – 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC}$ = 5 V (unless otherwise noted)

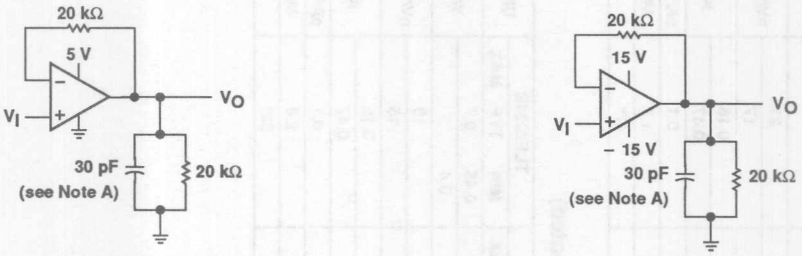
| PARAMETER | | TEST CONDITIONS | $T_A$ | TLE2024 | | | TLE2024A | | | TLE2024B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O$ = 1 V to 3 V, See Figure 1 | 25°C | | 0.5 | | | 0.5 | | | 0.5 | | V/μs |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz | 25°C | | 21 | | | 21 | | | 21 | | nV/√Hz |
| | | f = 1 kHz | 25°C | | 17 | | | 17 | | | 17 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.16 | | | 0.16 | | | 0.16 | | μV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.47 | | | 0.47 | | | 0.47 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.1 | | | 0.1 | | | 0.1 | | pA/√Hz |
| $B_1$ | Unity-gain bandwidth | See Figure 3 | 25°C | | 1.7 | | | 1.7 | | | 1.7 | | MHz |
| $\phi_m$ | Phase margin at unity gain | See Figure 3 | 25°C | | 47° | | | 47° | | | 47° | | |

## operating characteristics at specified free-air temperature, $V_{CC\pm}$ = ± 15 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2024 | | | TLE2024A | | | TLE2024B | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_O$ = ± 10 V, See Figure 1 | 25°C | 0.45 | 0.7 | | 0.45 | 0.7 | | 0.45 | 0.7 | | V/μs |
| | | | Full range | 0.4 | | | 0.4 | | | 0.4 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz | 25°C | | 19 | | | 19 | | | 19 | | nV/√Hz |
| | | f = 1 kHz | 25°C | | 15 | | | 15 | | | 15 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 to 1 Hz | 25°C | | 0.16 | | | 0.16 | | | 0.16 | | μV |
| | | f = 0.1 to 10 Hz | 25°C | | 0.47 | | | 0.47 | | | 0.47 | | |
| $I_n$ | Equivalent input noise current | | 25°C | | 0.1 | | | 0.1 | | | 0.1 | | pA/√Hz |
| $B_1$ | Unity-gain bandwidth | See Figure 3 | 25°C | | 2.8 | | | 2.8 | | | 2.8 | | MHz |
| $\phi_m$ | Phase margin at unity gain | See Figure 3 | 25°C | | 52° | | | 52° | | | 52° | | |

† Full range is – 55°C to 125°C.

## PARAMETER MEASUREMENT INFORMATION

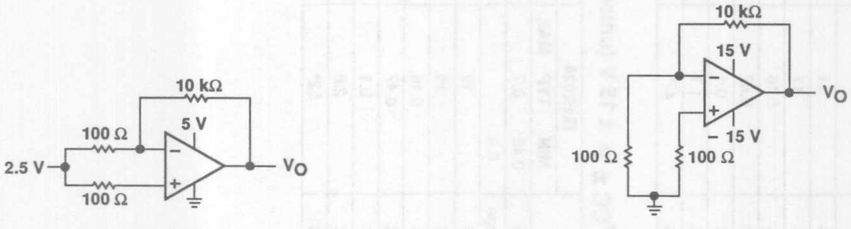


NOTE A: $C_L$ includes fixture capacitance.

(a) SINGLE-SUPPLY

(b) SPLIT-SUPPLY

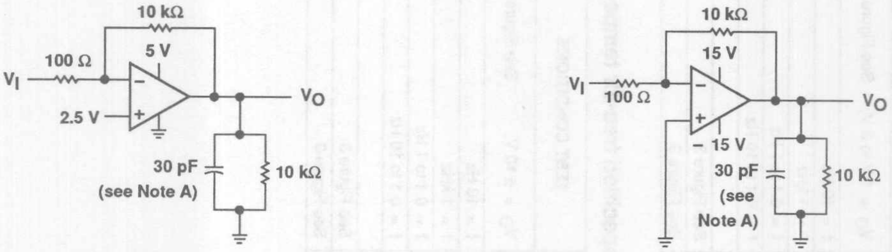
Figure 1. Slew Rate Test Circuit



(a) SINGLE-SUPPLY

(b) SPLIT-SUPPLY

Figure 2. Noise Voltage Test Circuit



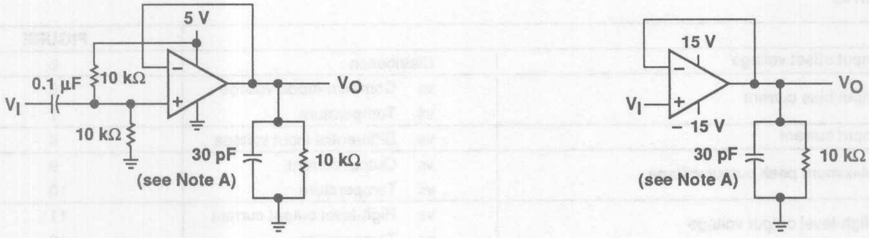
NOTE A: $C_L$ includes fixture capacitance.

(a) SINGLE-SUPPLY

(b) SPLIT-SUPPLY

Figure 3. Unity-Gain Bandwidth and Phase Margin Test Circuit

## PARAMETER MEASUREMENT INFORMATION



NOTE A: $C_L$ includes fixture capacitance.

(a) SINGLE-SUPPLY

(b) SPLIT-SUPPLY

Figure 4. Small-Signal Pulse Response Test Circuit

### typical values

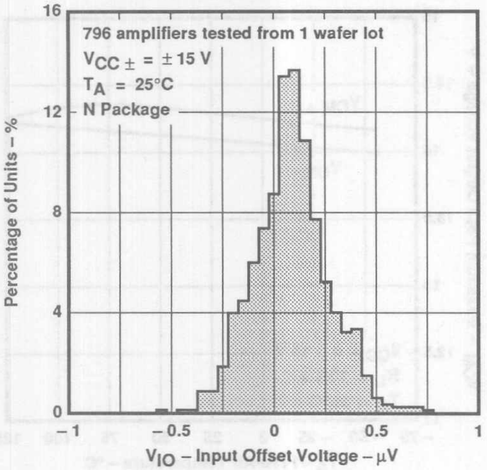
Typical values as presented in this data sheet represent the median (50% point) of device parametric performance.

## TYPICAL CHARACTERISTICS

### table of graphs

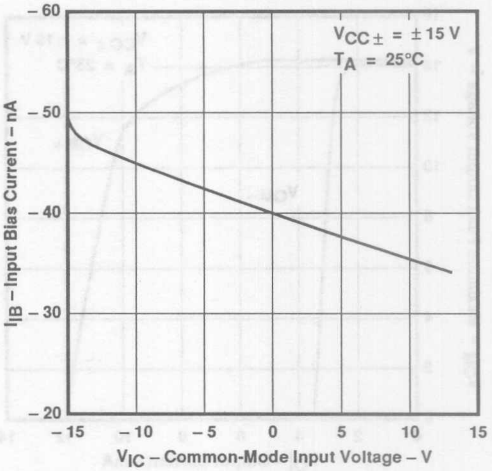
| | | | FIGURE |
|---|---|---|---|
| $V_{IO}$ | Input offset voltage | Distribution | 5 |
| $I_{IB}$ | Input bias current | vs Common-mode voltage | 6 |
| | | vs Temperature | 7 |
| $I_I$ | Input current | vs Differential input voltage | 8 |
| $V_{OM}$ | Maximum peak output voltage | vs Output current | 9 |
| | | vs Temperature | 10 |
| $V_{OH}$ | High-level output voltage | vs High-level output current | 11 |
| | | vs Temperature | 12 |
| $V_{OL}$ | Low-level output voltage | vs Low-level output current | 13 |
| | | vs Temperature | 14 |
| $V_{O(PP)}$ | Maximum peak-to-peak output voltage swing | vs Frequency | 15, 16 |
| $A_{VD}$ | Differential voltage amplification | vs Frequency | 17 |
| | | vs Temperature | 18 |
| $I_{OS}$ | Short-circuit output current | vs Supply voltage | 19, 21 |
| | | vs Temperature | 20, 22 |
| $I_{CC}$ | Supply current | vs Supply voltage | 23 |
| | | vs Temperature | 24 |
| CMRR | Common-mode rejection ratio | vs Frequency | 25 |
| SR | Slew rate | vs Temperature | 26 |
| | Pulse response | Small-signal | 27, 28 |
| | | Large-signal | 29, 30 |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | 0.1 to 1 Hz | 31 |
| | | 0.1 to 10 Hz | 32 |
| $V_n$ | Equivalent input noise voltage | vs Frequency | 33 |
| $B_1$ | Unity-gain bandwidth | vs Supply voltage | 34 |
| | | vs Temperature | 35 |
| $\phi_m$ | Phase margin | vs Supply voltage | 36 |
| | | vs Capacitive load | 37 |
| | | vs Temperature | 38 |
| | Phase shift | vs Frequency | 17 |

## TYPICAL CHARACTERISTICS[†]



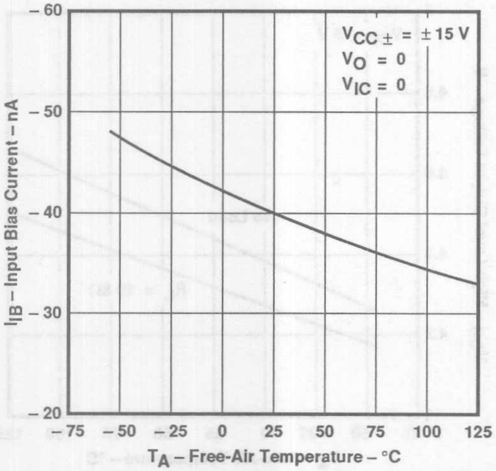
**TLE2024**
DISTRIBUTION OF
INPUT OFFSET VOLTAGE

Figure 5



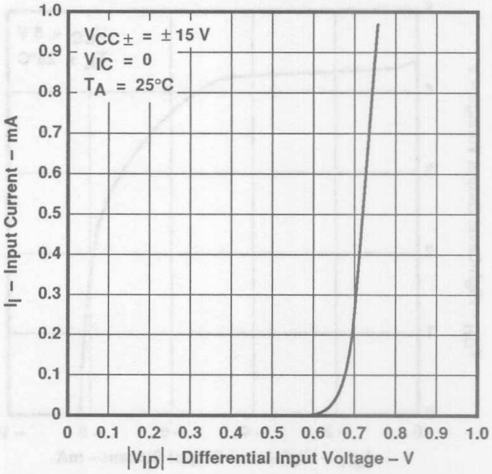
**TLE2024B**
INPUT BIAS CURRENT
vs
COMMON-MODE INPUT VOLTAGE

Figure 6



**TLE2024B**
INPUT BIAS CURRENT
vs
FREE-AIR TEMPERATURE

Figure 7



INPUT CURRENT
vs
DIFFERENTIAL INPUT VOLTAGE

Figure 8

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[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

TLE2024B
MAXIMUM PEAK OUTPUT VOLTAGE
vs
OUTPUT CURRENT

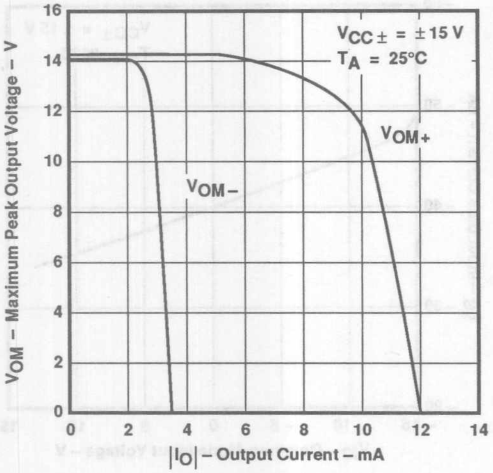


Figure 9

TLE2024B
MAXIMUM PEAK OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE

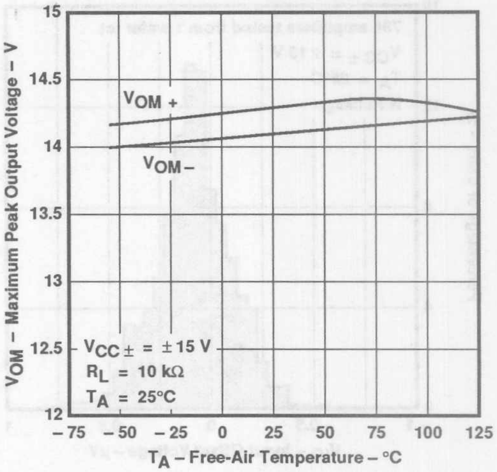


Figure 10

TLE2024B
HIGH-LEVEL OUTPUT VOLTAGE
vs
HIGH-LEVEL OUTPUT CURRENT

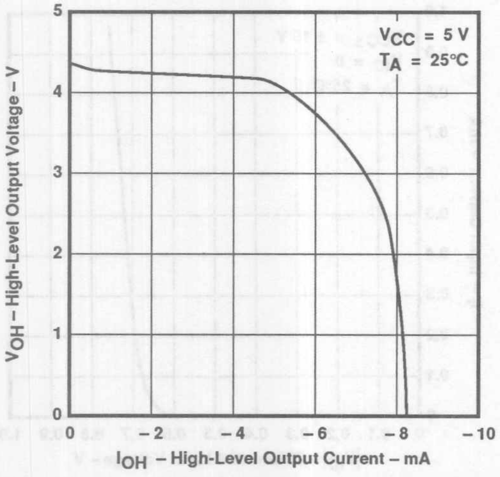


Figure 11

TLE2024B
HIGH-LEVEL OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE

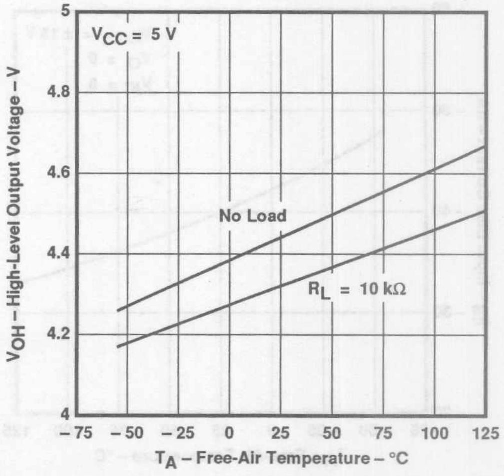


Figure 12

---

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

LOW-LEVEL OUTPUT VOLTAGE
vs
LOW-LEVEL OUTPUT CURRENT

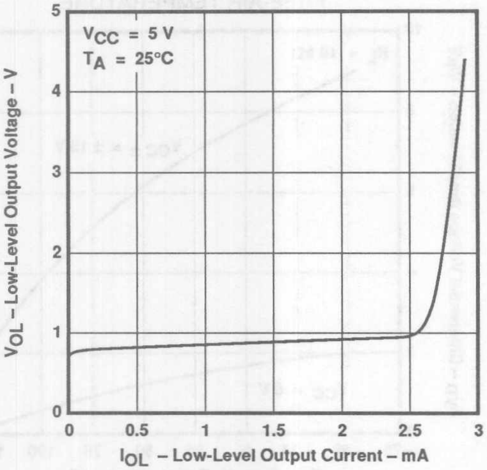


Figure 13

LOW-LEVEL OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE

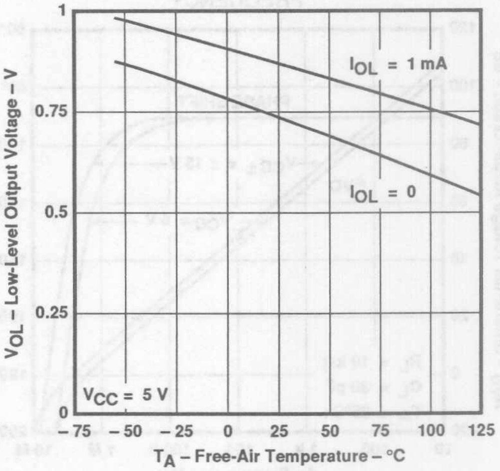


Figure 14

TLE2024B
MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE
vs
FREQUENCY

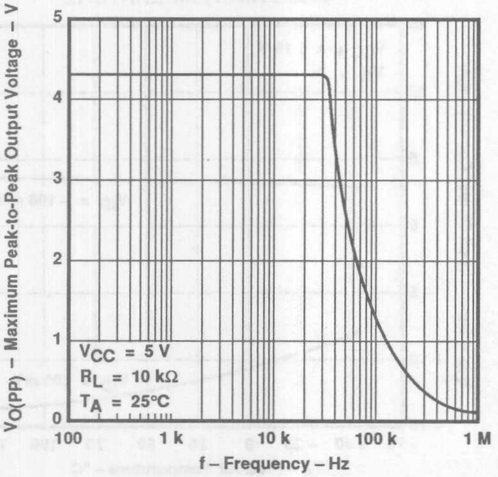


Figure 15

TLE2024B
MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE
vs
FREQUENCY

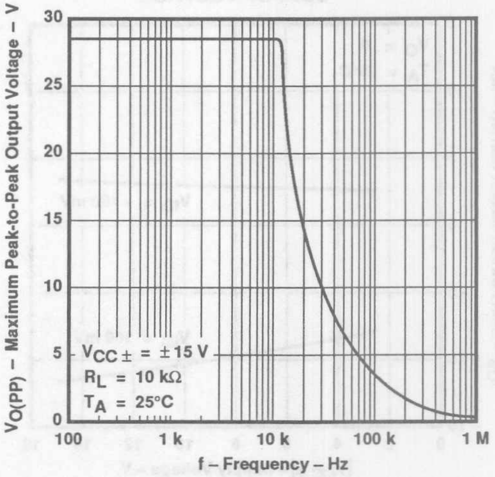
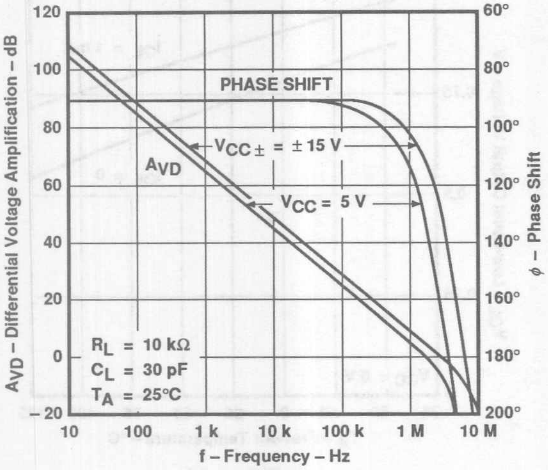


Figure 16

---

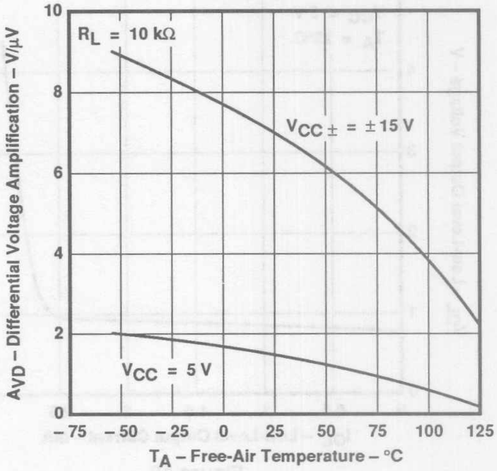
†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†



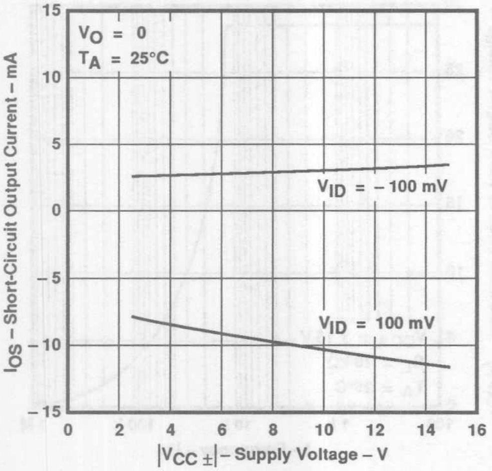
TLE2024
LARGE-SIGNAL DIFFERENTIAL VOLTAGE
AMPLIFICATION and PHASE SHIFT
vs
FREQUENCY

Figure 17



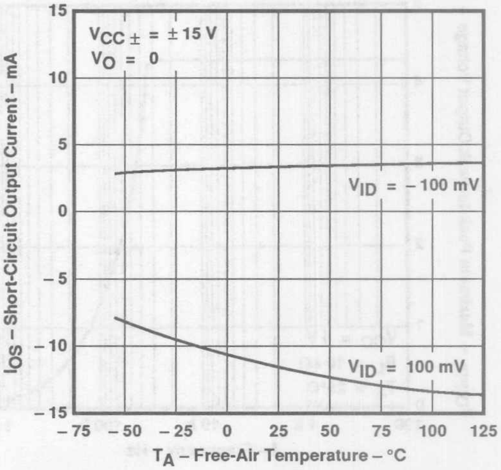
TLE2024B
LARGE-SIGNAL DIFFERENTIAL VOLTAGE
AMPLIFICATION
vs
FREE-AIR TEMPERATURE

Figure 18



SHORT-CIRCUIT OUTPUT CURRENT
vs
SUPPLY VOLTAGE

Figure 19



SHORT-CIRCUIT OUTPUT CURRENT
vs
FREE-AIR TEMPERATURE

Figure 20

---

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS[†]

SHORT-CIRCUIT OUTPUT CURRENT
vs
SUPPLY VOLTAGE

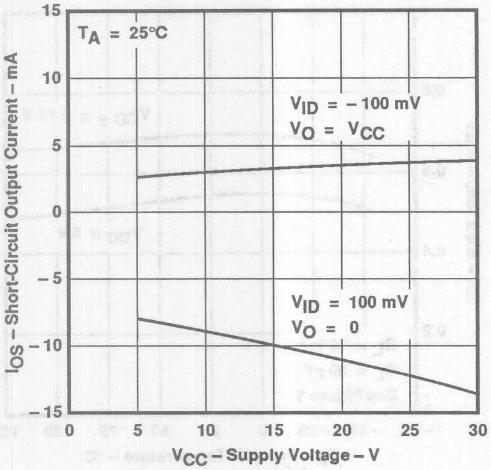


Figure 21

SHORT-CIRCUIT OUTPUT CURRENT
vs
FREE-AIR TEMPERATURE

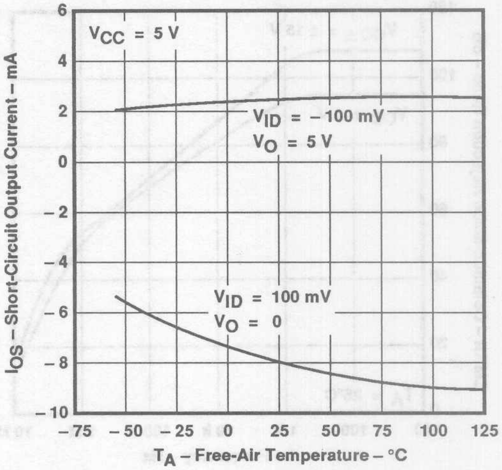


Figure 22

SUPPLY CURRENT
vs
SUPPLY VOLTAGE

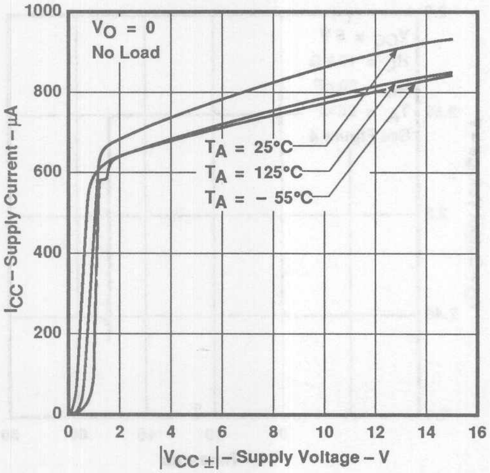


Figure 23

SUPPLY CURRENT
vs
FREE-AIR TEMPERATURE

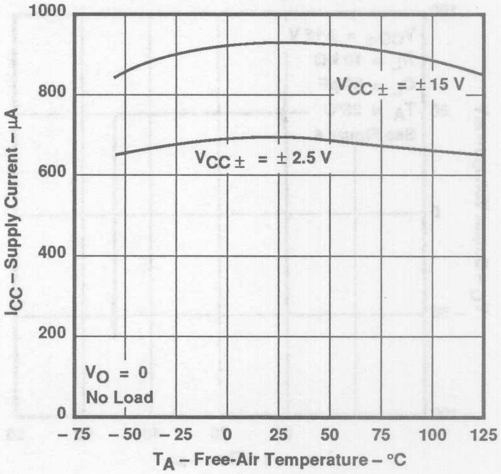


Figure 24

---

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS[†]

### TLE2024B COMMON-MODE REJECTION RATIO vs FREQUENCY

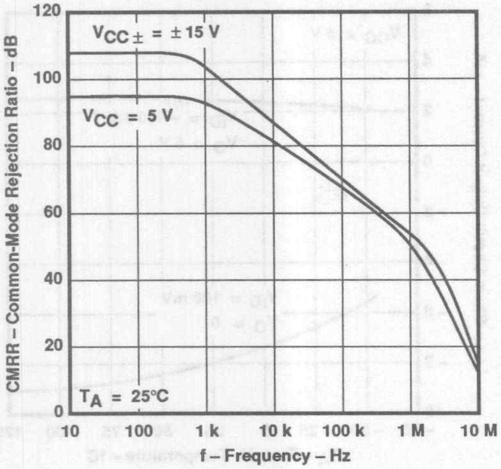


Figure 25

### SLEW RATE vs FREE-AIR TEMPERATURE

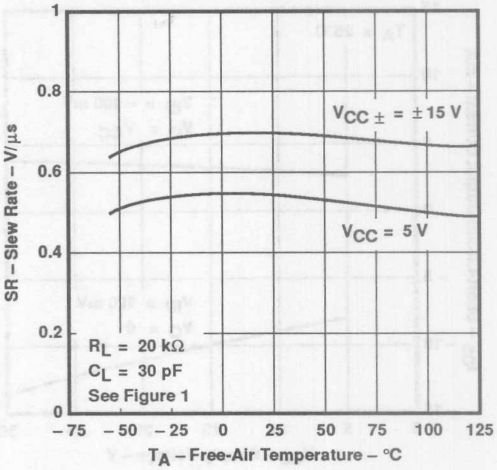


Figure 26

### VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE

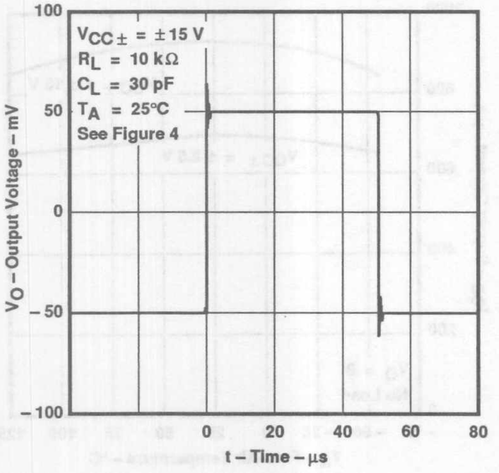


Figure 27

### VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE

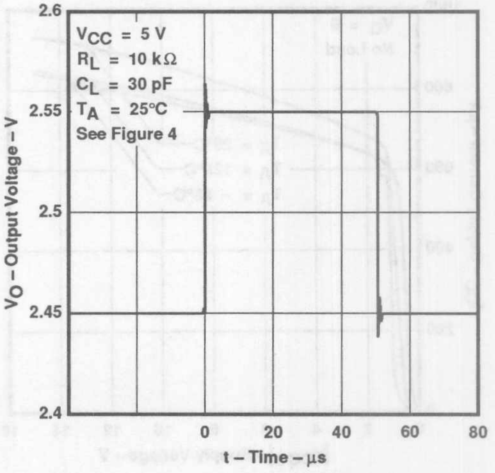


Figure 28

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[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS

VOLTAGE-FOLLOWER
LARGE-SIGNAL
PULSE RESPONSE

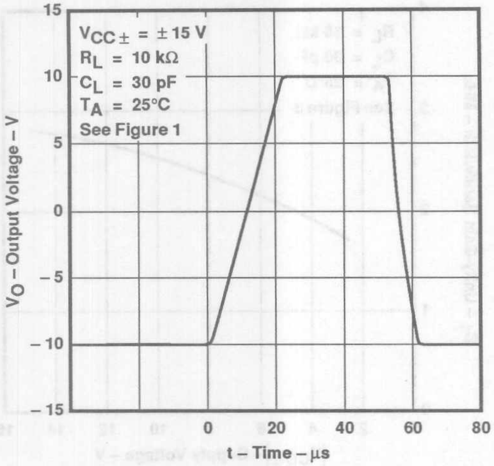

Figure 29

VOLTAGE-FOLLOWER
LARGE-SIGNAL
PULSE RESPONSE

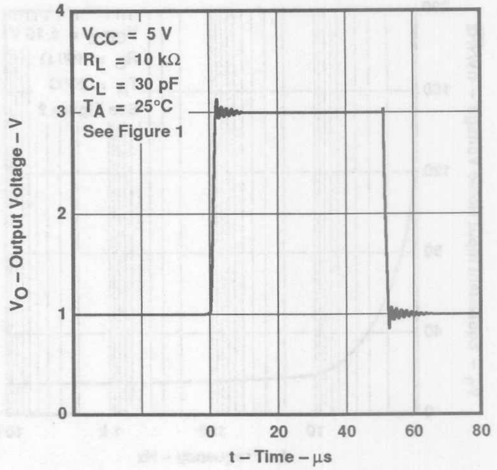

Figure 30

PEAK-TO-PEAK EQUIVALENT
INPUT NOISE VOLTAGE
0.1 TO 1 Hz

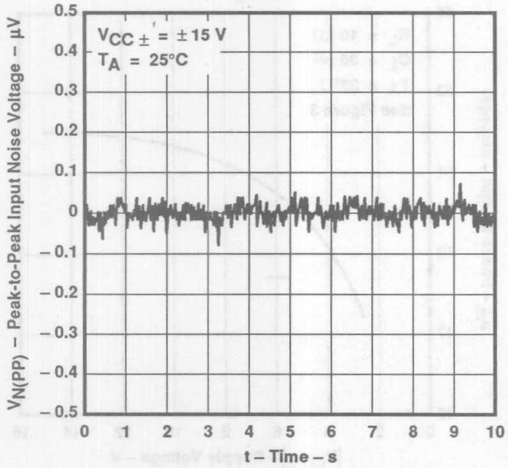

Figure 31

PEAK-TO-PEAK EQUIVALENT
INPUT NOISE VOLTAGE
0.1 TO 10 Hz

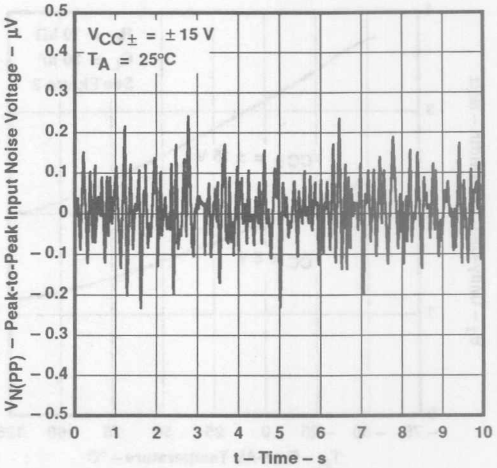

Figure 32

## TYPICAL CHARACTERISTICS†

EQUIVALENT INPUT NOISE VOLTAGE
vs
FREQUENCY

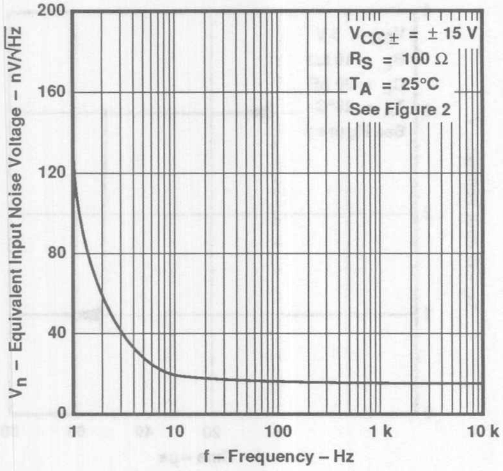

Figure 33

UNITY-GAIN BANDWIDTH
vs
SUPPLY VOLTAGE

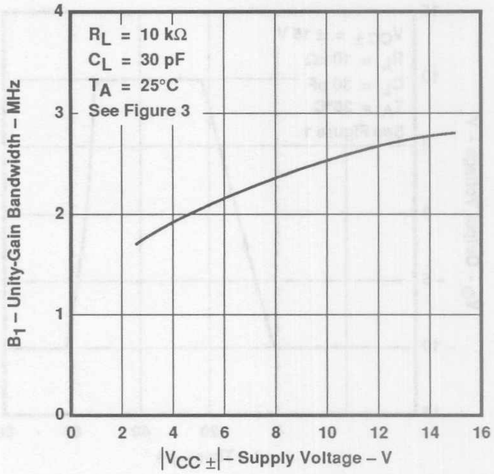

Figure 34

UNITY-GAIN BANDWIDTH
vs
FREE-AIR TEMPERATURE

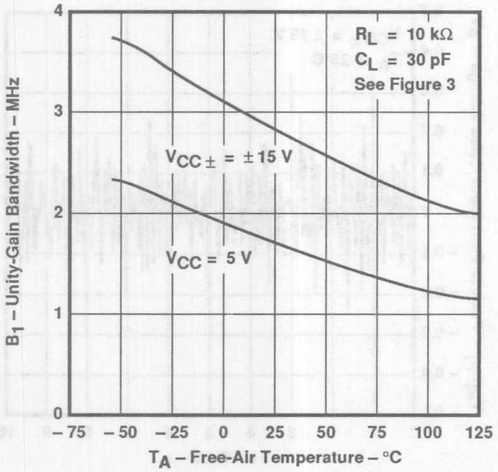

Figure 35

PHASE MARGIN
vs
SUPPLY VOLTAGE

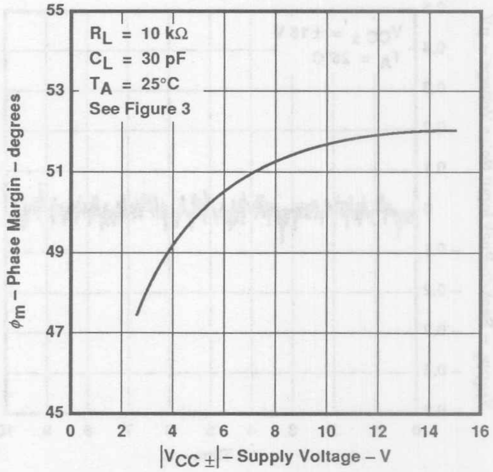

Figure 36

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†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

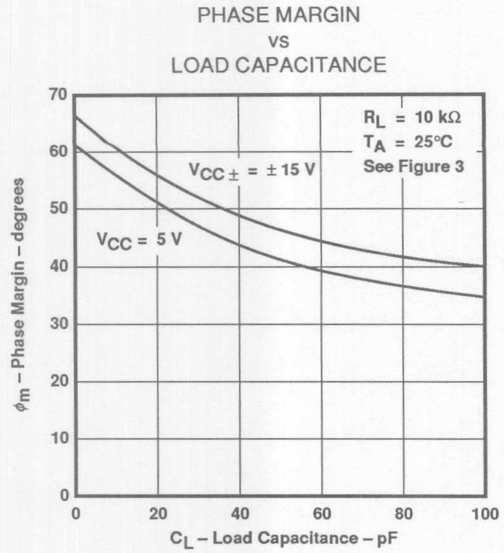


Figure 37

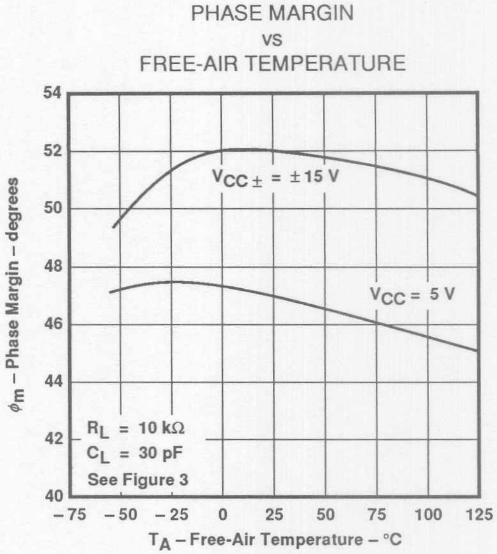


Figure 38

---

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## APPLICATION INFORMATION

### voltage-follower applications

The TLE2024 circuitry includes input protection diodes to limit the voltage across the input transistors; however, no provision is made in the circuit to limit the current if these diodes are forward-biased. Note that this condition can occur when the device is operated in the voltage-follower configuration and driven with a fast, large-signal pulse. It is recommended that a feedback resistor be used to limit the current to a maximum of 1 mA to prevent degradation of the device. Also, remember that this feedback resistor will form a pole with the input capacitance of the device. For feedback resistor values greater than 10 kΩ, this pole will degrade the amplifier's phase margin. This problem can be alleviated by adding a capacitor (20 pF to 50 pF) in parallel with the feedback resistor (see Figure 39).

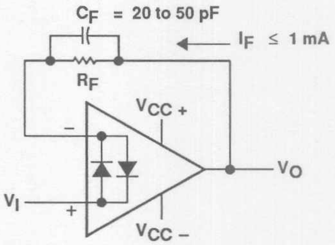


Figure 39. Voltage Follower

### input characteristics

The input of any unused amplifiers should be tied to ground to avoid possible oscillation.

# TLE2027, TLE2027A
# EXCALIBUR LOW-NOISE HIGH-SPEED PRECISION OPERATIONAL AMPLIFIERS

D3440, MAY 1990 – REVISED APRIL 1991

## available features

- **Outstanding Combination of DC Precision and AC Performance:**
  **Unity-Gain Bandwidth . . . 15 MHz Typ**
  **$V_n$ . . . . 3.3 nV/√Hz at f = 10 Hz Typ,**
  **2.5 nV/√Hz at f = 1 kHz Typ**
  **$V_{IO}$ . . . 25 µV Max**
  **$A_{VD}$ . . . 45 V/µV Typ, With $R_L$ = 2 kΩ,**
  **19 V/µV Typ, With $R_L$ = 600 Ω**
- **Available in Standard-Pinout Small-Outline Package**
- **Output Features Saturation Recovery Circuitry**
- **Macromodels and Statistical Information**

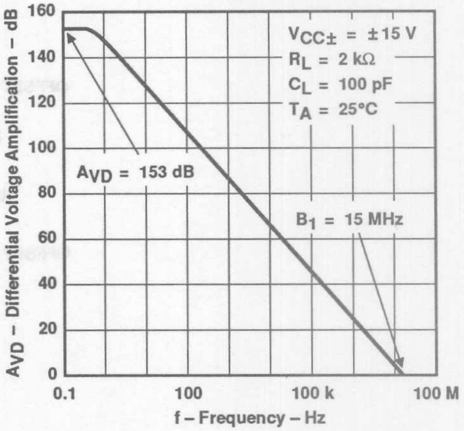
## description

The TLE2027 and TLE2027A contain innovative circuit design expertise and high-quality process control techniques to produce a level of ac performance and dc precision previously unavailable in single operational amplifiers. Manufactured using Texas Instruments state-of-the-art Excalibur process, these devices allow upgrades to systems that use lower-precision devices.

In the area of dc precision, the TLE2027 and TLE2027A offer maximum offset voltages of 100 µV and 25 µV, respectively, common-mode rejection ratio of 131 dB (typ), supply voltage rejection ratio of 144 dB (typ), and dc gain of 45 V/µV (typ).

Ac performance is highlighted by a typical unity-gain bandwidth specification of 15 MHz, 55° of phase margin, and noise voltage specifications of 3.3 nV/√Hz and 2.5 nV/√Hz at frequencies of 10 Hz and 1 kHz, respectively.

**LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION vs FREQUENCY**



Both the TLE2027 and TLE2027A are available in a wide variety of packages, including the industry-standard 8-pin small-outline version for high-density system applications. The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from −40°C to 105°C. The M-suffix devices are characterized for operation over the full military temperature range of −55°C to 125°C.

**AVAILABLE OPTIONS**

| $T_A$ | $V_{IO}$ max AT 25°C | PACKAGE | | | | |
|---|---|---|---|---|---|---|
| | | SMALL-OUTLINE (D) | CHIP CARRIER (FK) | CERAMIC DIP (JG) | METAL CAN (L) | PLASTIC DIP (P) |
| 0°C to 70°C | 25 µV | TLE2027ACD | — | — | — | TLE2027ACP |
| | 100 µV | TLE2027CD | — | — | — | TLE2027CP |
| – 40°C to 105°C | 25 µV | TLE2027AID | — | — | — | TLE2027AIP |
| | 100 µV | TLE2027ID | — | — | — | TLE2027IP |
| – 55°C to 125°C | 25 µV | TLE2027AMD | TLE2027AMFK | TLE2027AMJG | TLE2027AML | TLE2027AMP |
| | 100 µV | TLE2027MD | TLE2027MFK | TLE2027MJG | TLE2027ML | TLE2027MP |

D packages are available taped and reeled. Add "R" suffix to device type, (e.g., TLE2027ACDR).

PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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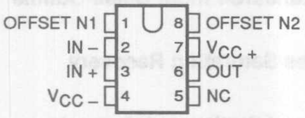
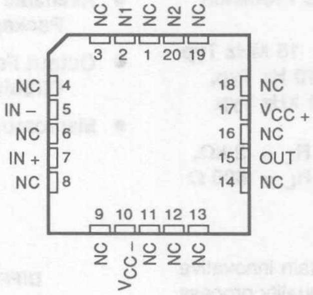
On products compliant to MIL-STD-883, Class B, all parameters are tested unless otherwise noted. On all other products, production processing does not necessarily include testing of all parameters.

# TLE2027, TLE2027A
# EXCALIBUR LOW-NOISE HIGH-SPEED PRECISION OPERATIONAL AMPLIFIERS

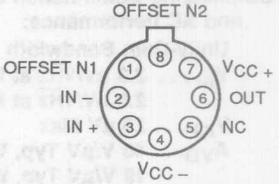
D, JG, OR P PACKAGE
(TOP VIEW)



FK PACKAGE
(TOP VIEW)



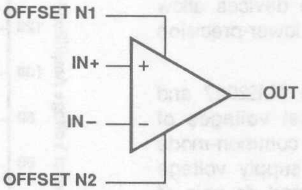
L PACKAGE
(TOP VIEW)



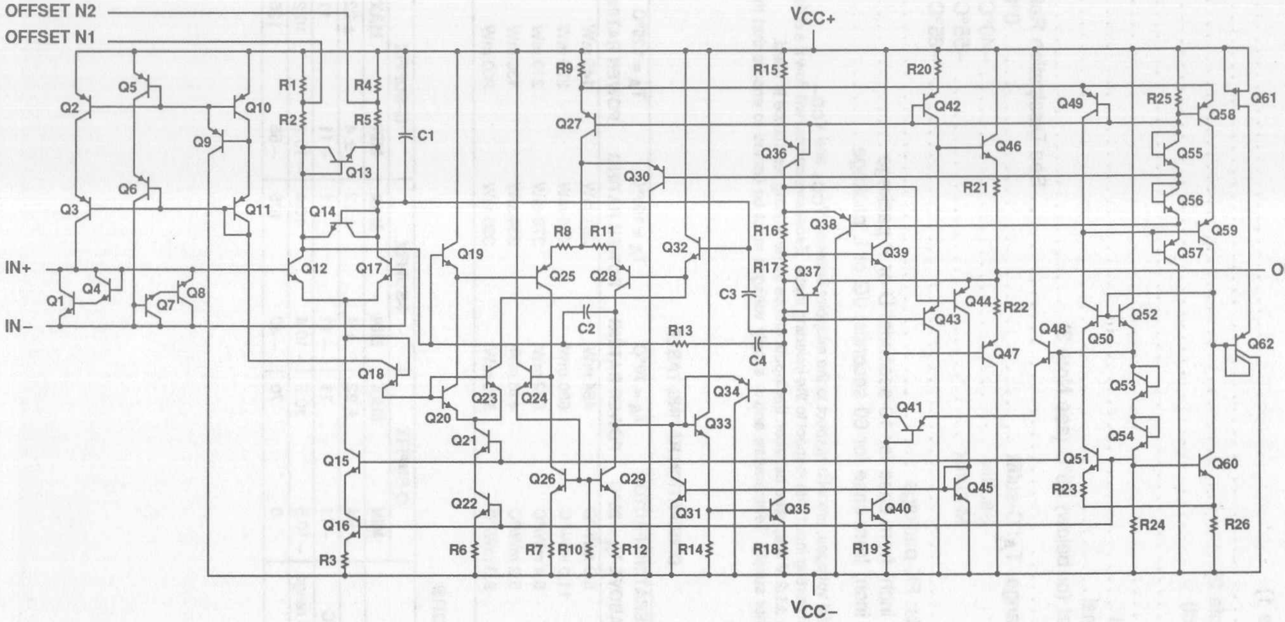
Pin 4 of the L package is in electrical contact with the case.

NC – No internal connection

## symbol



## equivalent schematic



## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|---|
| Supply voltage, $V_{CC+}$ (see Note 1) | 22 V |
| Supply voltage, $V_{CC-}$ | −22 V |
| Differential input voltage (see Note 2) | ±1.2 V |
| Input voltage range, $V_I$ (any input) | $V_{CC\pm}$ |
| Input current, $I_I$ (each input) | ±1 mA |
| Output current, $I_O$ | ±50 mA |
| Total current into $V_{CC+}$ terminal | 50 mA |
| Total current out of $V_{CC-}$ terminal | 50 mA |
| Duration of short-circuit current at (or below) 25°C (see Note 3) | unlimited |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range, $T_A$: C-suffix | 0°C to 70°C |
| I-suffix | −40°C to 105°C |
| M-suffix | −55°C to 125°C |
| Storage temperature range | −65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG or L package | 300°C |

NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between $V_{CC+}$ and $V_{CC-}$.

2. Differential voltages are at the noninverting input with respect to the inverting input. Excessive current will flow if a differential input voltage in excess of approximately ±1.2 V is applied between the inputs unless some limiting resistance is used.

3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \le 25°C$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25°C$ | $T_A = 70°C$ POWER RATING | $T_A = 105°C$ POWER RATING | $T_A = 125°C$ POWER RATING |
|---|---|---|---|---|---|
| D | 725 mW | 5.8 mW/°C | 464 mW | 261 mW | 145 mW |
| FK | 1375 mW | 11.0 mW/°C | 880 mW | 495 mW | 275 mW |
| JG | 1050 mW | 8.4 mW/°C | 672 mW | 378 mW | 210 mW |
| L | 650 mW | 5.2 mW/°C | 416 mW | 234 mW | 130 mW |
| P | 1000 mW | 8.0 mW/°C | 640 mW | 360 mW | 200 mW |

## recommended operating conditions

| | | C-SUFFIX | | I-SUFFIX | | M-SUFFIX | | UNIT |
|---|---|---|---|---|---|---|---|---|
| | | MIN | MAX | MIN | MAX | MIN | MAX | |
| Supply voltage, $V_{CC\pm}$ | | ±4 | ±22 | ±4 | ±22 | ±4 | ±22 | V |
| Common-mode input voltage, $V_{IC}$ | $T_A$ = 25°C | −11 | 11 | −11 | 11 | −11 | 11 | V |
| | $T_A$ = Full range | −10.5 | 10.5 | −10.4 | 10.4 | −10.2 | 10.2 | |
| Operating free-air temperature, $T_A$ | | 0 | 70 | −40 | 105 | −55 | 125 | °C |

## electrical characteristics at specified free-air temperature, $V_{CC\pm}$ = ±15 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2027C | | | TLE2027AC | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC}$ = 0, $R_S$ = 50 Ω | 25°C | | 20 | 100 | | 10 | 25 | µV |
| | | | Full range | | | 145 | | | 70 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 0.4 | 1 | | 0.2 | 1 | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.006 | 1 | | 0.006 | 1 | µV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 6 | 90 | | 6 | 90 | nA |
| | | | Full range | | | 150 | | | 150 | |
| $I_{IB}$ | Input bias current | | 25°C | | 15 | 90 | | 15 | 90 | nA |
| | | | Full range | | | 150 | | | 150 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S$ = 50 Ω | 25°C | – 11 to 11 | – 13 to 13 | | – 11 to 11 | – 13 to 13 | | V |
| | | | Full range | – 10.5 to 10.5 | | | – 10.5 to 10.5 | | | |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $R_L$ = 600 Ω | 25°C | 10.5 | | | 10.5 | | | V |
| | | | Full range | 10 | | | 10 | | | |
| | | $R_L$ = 2 kΩ | 25°C | 12 | | | 12 | | | |
| | | | Full range | 11 | | | 11 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | $R_L$ = 600 Ω | 25°C | – 10.5 | – 13 | | –10.5 | –13 | | V |
| | | | Full range | – 10 | | | – 10 | | | |
| | | $R_L$ = 2 kΩ | 25°C | – 12 | – 13.5 | | – 12 | –13.5 | | |
| | | | Full range | – 11 | | | – 11 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O$ = ± 11 V, $R_L$ = 2 kΩ | 25°C | 5 | 45 | | 10 | 45 | | V/µV |
| | | $V_O$ = ± 10 V, $R_L$ = 2 kΩ | Full range | 2 | | | 4 | | | |
| | | $V_O$ = ± 10 V, $R_L$ = 1 kΩ | 25°C | 3.5 | 38 | | 8 | 38 | | |
| | | | Full range | 1 | | | 2.5 | | | |
| | | $V_O$ = ± 10 V, $R_L$ = 600 Ω | 25°C | 2 | 19 | | 5 | 19 | | |
| | | | Full range | 0.5 | | | 2 | | | |
| $c_i$ | Input capacitance | | 25°C | | 8 | | | 8 | | pF |
| $z_o$ | Open-loop output impedance | $I_O$ = 0 | 25°C | | 50 | | | 50 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC}$ = $V_{ICR}$ min, $R_S$ = 50 Ω | 25°C | 100 | 131 | | 117 | 131 | | dB |
| | | | Full range | 98 | | | 114 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm}$ = ± 4 V to ± 18 V, $R_S$ = 50 Ω | 25°C | 94 | 144 | | 110 | 144 | | dB |
| | | $V_{CC\pm}$ = ± 4 V to ± 18 V, $R_S$ = 50 Ω | Full range | 92 | | | 106 | | | |
| $I_{CC}$ | Supply current | $V_O$ = 0, No Load | 25°C | | 3.8 | 5.3 | | 3.8 | 4.7 | mA |
| | | | Full range | | | 5.6 | | | 4.8 | |

†Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A$ = 150°C extrapolated to $T_A$ = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V

| | PARAMETER | TEST CONDITIONS | $T_A$† | TLE2027C | | | TLE2027AC | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $R_L = 2\ k\Omega$, $C_L = 100\ pF$, See Figure 1 | 25°C | 1.7 | 2.8 | | 1.7 | 2.8 | | V/µs |
| | | | Full range | 1.2 | | | 1.2 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | $R_S = 100\ \Omega$, f = 10 Hz | 25°C | | 3.3 | 8 | | 3.3 | 4.5 | nV/√Hz |
| | | $R_S = 100\ \Omega$, f = 1 kHz | | | 2.5 | 4.5 | | 2.5 | 3.8 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | 25°C | | 50 | 250 | | 50 | 130 | nV |
| $I_n$ | Equivalent input noise current | f = 10 Hz | 25°C | | 1.5 | 4 | | 1.5 | 4 | pA/√Hz |
| | | f = 1 kHz | | | 0.4 | 0.6 | | 0.4 | 0.6 | |
| THD | Total harmonic distortion | $V_O = \pm 10$ V, $A_{VD} = 1$, See Note 5 | 25°C | | < 0.002% | | | < 0.002% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L = 2\ k\Omega$, $C_L = 100\ pF$ | 25°C | 7 | 13 | | 9 | 13 | | MHz |
| $B_{OM}$ | Maximum output-swing bandwidth | $R_L = 2\ k\Omega$ | 25°C | | 30 | | | 30 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L = 2\ k\Omega$, $C_L = 100\ pF$ | 25°C | | 55° | | | 55° | | |

† Full range is 0°C to 70°C.

NOTE 5: Measured distortion of the source used in the analysis was 0.002%.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2027I | | | TLE2027AI | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 20 | 100 | | 10 | 25 | µV |
| | | | Full range | | | 180 | | | 105 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 0.4 | 1 | | 0.2 | 1 | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.006 | 1 | | 0.006 | 1 | µV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 6 | 90 | | 6 | 90 | nA |
| | | | Full range | | | 150 | | | 150 | |
| $I_{IB}$ | Input bias current | | 25°C | | 15 | 90 | | 15 | 90 | nA |
| | | | Full range | | | 150 | | | 150 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | 25°C | − 11 to 11 | − 13 to 13 | | − 11 to 11 | − 13 to 13 | | V |
| | | | Full range | − 10.4 to 10.4 | | | − 10.4 to 10.4 | | | |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $R_L = 600\ \Omega$ | 25°C | 10.5 | | | 10.5 | | | V |
| | | | Full range | 10 | | | 10 | | | |
| | | $R_L = 2\ k\Omega$ | 25°C | 12 | | | 12 | | | |
| | | | Full range | 11 | | | 11 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | $R_L = 600\ \Omega$ | 25°C | − 10.5 | − 13 | | − 10.5 | − 13 | | V |
| | | | Full range | − 10 | | | − 10 | | | |
| | | $R_L = 2\ k\Omega$ | 25°C | − 12 | − 13.5 | | − 12 | − 13.5 | | |
| | | | Full range | − 11 | | | − 11 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = \pm 11$ V, $R_L = 2\ k\Omega$ | 25°C | 5 | 45 | | 10 | 45 | | V/µV |
| | | $V_O = \pm 10$ V, $R_L = 2\ k\Omega$ | Full range | 2 | | | 3.5 | | | |
| | | $V_O = \pm 10$ V, $R_L = 1\ k\Omega$ | 25°C | 3.5 | 38 | | 8 | 38 | | |
| | | | Full range | 1 | | | 2.2 | | | |
| | | $V_O = \pm 10$ V, $R_L = 600\ \Omega$ | 25°C | 2 | 19 | | 5 | 19 | | |
| | | | Full range | 0.5 | | | 1.1 | | | |
| $c_i$ | Input capacitance | | 25°C | | 8 | | | 8 | | pF |
| $z_o$ | Open-loop output impedance | $I_O = 0$ | 25°C | | 50 | | | 50 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min,<br>$R_S = 50\ \Omega$ | 25°C | 100 | 131 | | 117 | 131 | | dB |
| | | | Full range | 96 | | | 113 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 4$ V to $\pm 18$ V,<br>$R_S = 50\ \Omega$ | 25°C | 94 | 144 | | 110 | 144 | | dB |
| | | $V_{CC\pm} = \pm 4$ V to $\pm 18$ V,<br>$R_S = 50\ \Omega$ | Full range | 90 | | | 105 | | | |
| $I_{CC}$ | Supply current | $V_O = 0$, No Load | 25°C | | 3.8 | 5.3 | | 3.8 | 4.7 | mA |
| | | | Full range | | | 5.6 | | | 4.9 | |

†Full range is −40°C to 105°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150$°C extrapolated to $T_A = 25$°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2027I | | | TLE2027AI | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $R_L = 2$ kΩ, $C_L = 100$ pF, See Figure 1 | 25°C | 1.7 | 2.8 | | 1.7 | 2.8 | | V/μs |
| | | | Full range | 1.1 | | | 1.1 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | $R_S = 100$ Ω, $f = 10$ Hz | 25°C | | 3.3 | 8 | | 3.3 | 4.5 | nV/√Hz |
| | | $R_S = 100$ Ω, $f = 1$ kHz | | | 2.5 | 4.5 | | 2.5 | 3.8 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | $f = 0.1$ Hz to 10 Hz | 25°C | | 50 | 250 | | 50 | 130 | nV |
| $I_n$ | Equivalent input noise current | $f = 10$ Hz | 25°C | | 1.5 | 4 | | 1.5 | 4 | pA/√Hz |
| | | $f = 1$ kHz | | | 0.4 | 0.6 | | 0.4 | 0.6 | |
| THD | Total harmonic distortion | $V_O = \pm 10$ V, $A_{VD} = 1$, See Note 5 | 25°C | | < 0.002% | | | < 0.002% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L = 2$ kΩ, $C_L = 100$ pF | 25°C | 7 | 13 | | 9 | 13 | | MHz |
| $B_{OM}$ | Maximum output-swing bandwidth | $R_L = 2$ kΩ | 25°C | | 30 | | | 30 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L = 2$ kΩ, $C_L = 100$ pF | 25°C | | 55° | | | 55° | | |

†Full range is −40°C to 105°C.

NOTE 5: Measured distortion of the source used in the analysis was 0.002%.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2027M | | | TLE2027AM | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 20 | 100 | | 10 | 25 | µV |
| | | | Full range | | | 200 | | | 105 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 0.4 | 1* | | 0.2 | 1* | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.006 | 1* | | 0.006 | 1* | µV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 6 | 90 | | 6 | 90 | nA |
| | | | Full range | | | 150 | | | 150 | |
| $I_{IB}$ | Input bias current | | 25°C | | 15 | 90 | | 15 | 90 | nA |
| | | | Full range | | | 150 | | | 150 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | 25°C | −11<br>to<br>11 | −13<br>to<br>13 | | −11<br>to<br>11 | −13<br>to<br>13 | | V |
| | | | Full range | −10.3<br>to<br>10.3 | | | −10.4<br>to<br>10.4 | | | |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $R_L = 600\ \Omega$ | 25°C | 10.5 | | | 10.5 | | | V |
| | | | Full range | 10 | | | 10 | | | |
| | | $R_L = 2\ k\Omega$ | 25°C | 12 | | | 12 | | | |
| | | | Full range | 11 | | | 11 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | $R_L = 600\ \Omega$ | 25°C | −10.5 | −13 | | −10.5 | −13 | | V |
| | | | Full range | −10 | | | −10 | | | |
| | | $R_L = 2\ k\Omega$ | 25°C | −12 | −13.5 | | −12 | −13.5 | | |
| | | | Full range | −11 | | | −11 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = \pm 11$ V, $R_L = 2\ k\Omega$ | 25°C | 5 | 45 | | 10 | 45 | | V/µV |
| | | $V_O = \pm 10$ V, $R_L = 2\ k\Omega$ | Full range | 2.5 | | | 3.5 | | | |
| | | $V_O = \pm 10$ V, $R_L = 1\ k\Omega$ | 25°C | 3.5 | 38 | | 8 | 38 | | |
| | | | Full range | 1.8 | | | 2.2 | | | |
| | | $V_O = \pm 10$ V, $R_L = 600\ \Omega$ | 25°C | 2 | 19 | | 5 | 19 | | |
| $c_i$ | Input capacitance | | 25°C | | 8 | | | 8 | | pF |
| $z_o$ | Open-loop output impedance | $I_O = 0$ | 25°C | | 50 | | | 50 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min,<br>$R_S = 50\ \Omega$ | 25°C | 100 | 131 | | 117 | 131 | | dB |
| | | | Full range | 96 | | | 113 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 4$ V to $\pm 18$ V,<br>$R_S = 50\ \Omega$ | 25°C | 94 | 144 | | 110 | 144 | | dB |
| | | $V_{CC\pm} = \pm 4$ V to $\pm 18$ V,<br>$R_S = 50\ \Omega$ | Full range | 90 | | | 105 | | | |
| $I_{CC}$ | Supply current | $V_O = 0$, No Load | 25°C | | 3.8 | 5.3 | | 3.8 | 4.7 | mA |
| | | | Full range | | | 5.6 | | | 5 | |

*On products compliant to MIL-STD-883, Class B, this parameter is not production tested.

†Full range is −55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics, $V_{CC\pm} = \pm 15$ V, $T_A = 25°C$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2027M | | | TLE2027AM | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $R_L = 2\ k\Omega$, $C_L = 100$ pF, See Figure 1 | 25°C | 1.7 | 2.8 | | 1.7 | 2.8 | | V/μs |
| | | | Full range | 1 | | | 1 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | $R_S = 100\ \Omega$, f = 10 Hz | 25°C | | 3.3 | 8* | | 3.3 | 4.5* | nV/√Hz |
| | | $R_S = 100\ \Omega$, f = 1 kHz | | | 2.5 | 4.5* | | 2.5 | 3.8* | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | 25°C | | 50 | 250* | | 50 | 130* | nV |
| $I_n$ | Equivalent input noise current | f = 10 Hz | 25°C | | 1.5 | 4* | | 1.5 | 4* | pA/√Hz |
| | | f = 1 kHz | | | 0.4 | 0.6* | | 0.4 | 0.6* | |
| THD | Total harmonic distortion | $V_O = \pm 10$ V, $A_{VD} = 1$, See Note 5 | 25°C | | < 0.002% | | | < 0.002% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L = 2\ k\Omega$, $C_L = 100$ pF | 25°C | 7* | 13 | | 9* | 13 | | MHz |
| $B_{OM}$ | Maximum output-swing bandwidth | $R_L = 2\ k\Omega$ | 25°C | | 30 | | | 30 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L = 2\ k\Omega$, $C_L = 100$ pF | 25°C | | 55° | | | 55° | | |

*On products compliant to MIL-STD-883, Class B, this parameter is not production tested.

†Full range is −55°C to 125°C.

NOTE 5: Measured distortion of the source used in the analysis was 0.002%.

## PARAMETER MEASUREMENT INFORMATION

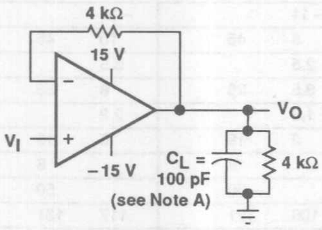


Figure 1. Slew Rate Test Circuit

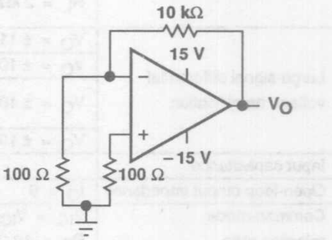


Figure 2. Noise Voltage Test Circuit

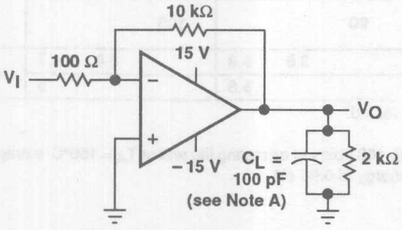


Figure 3. Unity-Gain Bandwidth and Phase Margin Test Circuit

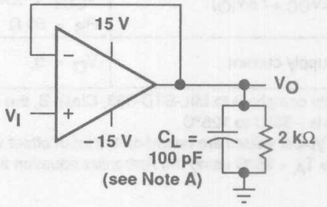


Figure 4. Small-Signal Pulse Response Test Circuit

NOTE A: $C_L$ includes fixture capacitance.

## PARAMETER MEASUREMENT INFORMATION

### typical values

Typical values as presented in this data sheet represent the median (50% point) of device parametric performance.

### initial estimates of parameter distributions

In the on-going program of improving data sheets and supplying more information to our customer, Texas Instruments has added an estimate of not only the "typical" values but also the spread around these values. These are in the form of distribution bars that show the 95% (upper) points and the 5% (lower) points from our characterization of the initial wafer lots of this new device type (see Figure 5). The distribution bars are shown at the points where data was actually collected. The 95% and 5% points are used instead of ±3 sigma since some of the distributions are not true Gaussian distributions.

The number of units tested and the number of different wafer lots used are on all of the graphs where distribution bars are shown. As noted in Figure 5, there were a total of 835 units from 2 wafer lots. In this case, there is a very good estimate for the within-lot variability and a possibly poor estimate of the lot-to-lot variability. This will always be the case on newly released products since there will only be data available from a few wafer lots.

The distribution bars are not intended to replace the minimum and maximum limits in the electrical tables. Each distribution bar represents 90% of the total units tested at a specific temperature. While 10% of the units tested fell outside any given distribution bar, this should not be interpreted to mean that the same individual devices fell outside every distribution bar.

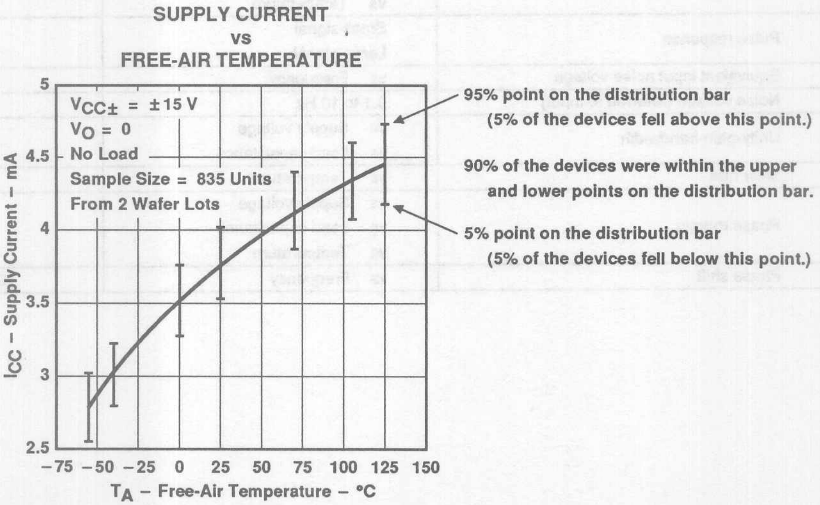


Figure 5. Sample Graph with Distribution Bars

## TYPICAL CHARACTERISTICS

### table of graphs

| | | | FIGURE |
|---|---|---|---|
| $V_{IO}$ | Input offset voltage | Distribution | 6 |
| $\Delta V_{IO}$ | Input offset voltage change | vs Time after power on | 7, 8 |
| $I_{IO}$ | Input offset current | vs Temperature | 9 |
| $I_{IB}$ | Input bias current | vs Common-mode input voltage | 10 |
| | | vs Temperature | 11 |
| $I_I$ | Input current | vs Differential input voltage | 12 |
| $V_{O(PP)}$ | Maximum peak-to-peak output voltage | vs Frequency | 13 |
| $V_{OM}$ | Maximum peak output voltage | vs Load resistance | 14, 15 |
| | | vs Temperature | 16, 17 |
| $A_{VD}$ | Large-signal differential voltage amplification | vs Supply voltage | 18 |
| | | vs Load resistance | 20 |
| | | vs Frequency | 19, 21 |
| | | vs Temperature | 22 |
| $z_o$ | Output impedance | vs Frequency | 23 |
| CMRR | Common-mode rejection ratio | vs Frequency | 24 |
| $k_{SVR}$ | Supply voltage rejection ratio | vs Frequency | 25 |
| $I_{OS}$ | Short-circuit output current | vs Supply voltage | 26, 27 |
| | | vs Time | 28, 29 |
| | | vs Temperature | 30, 31 |
| $I_{CC}$ | Supply current | vs Supply voltage | 32 |
| | | vs Temperature | 33 |
| | Pulse response | Small-signal | 34 |
| | | Large-signal | 35 |
| $V_n$ | Equivalent input noise voltage | vs Frequency | 36 |
| | Noise voltage (referred to input) | 0.1 to 10 Hz | 37 |
| $B_1$ | Unity-gain-bandwidth | vs Supply voltage | 38 |
| | | vs Load capacitance | 39 |
| SR | Slew rate | vs Temperature | 40 |
| $\phi_m$ | Phase margin | vs Supply voltage | 41 |
| | | vs Load capacitance | 42 |
| | | vs Temperature | 43 |
| $\phi$ | Phase shift | vs Frequency | 19, 21 |

## TYPICAL CHARACTERISTICS†

TLE2027
DISTRIBUTION OF
INPUT OFFSET VOLTAGE

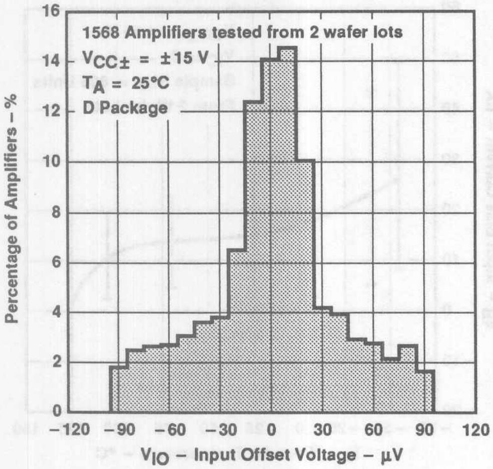


Figure 6

INPUT OFFSET VOLTAGE CHANGE
vs
TIME AFTER POWER ON

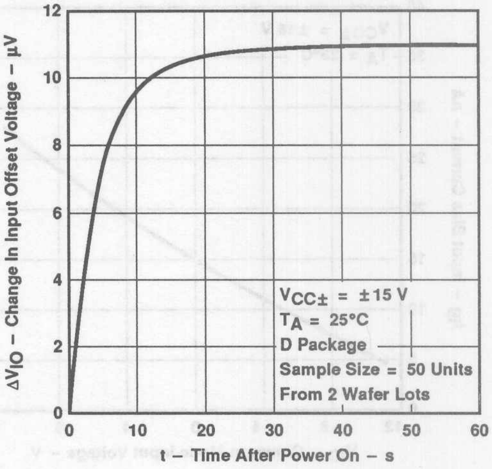


Figure 7

INPUT OFFSET VOLTAGE CHANGE
vs
TIME AFTER POWER ON

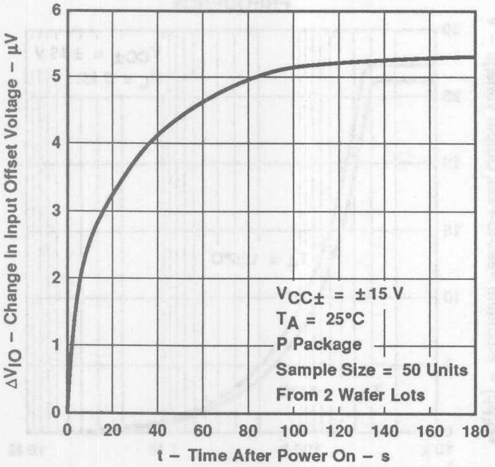


Figure 8

INPUT OFFSET CURRENT
vs
FREE-AIR TEMPERATURE

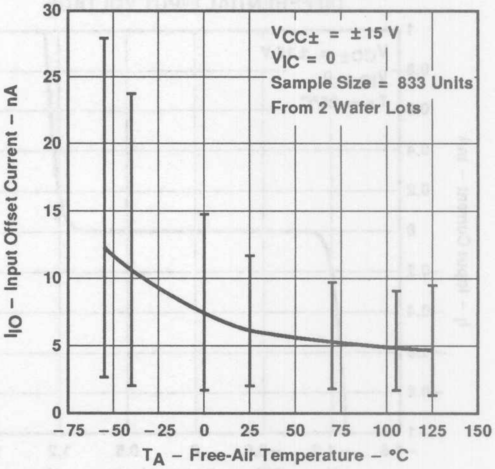


Figure 9

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†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

INPUT BIAS CURRENT
vs
COMMON-MODE INPUT VOLTAGE

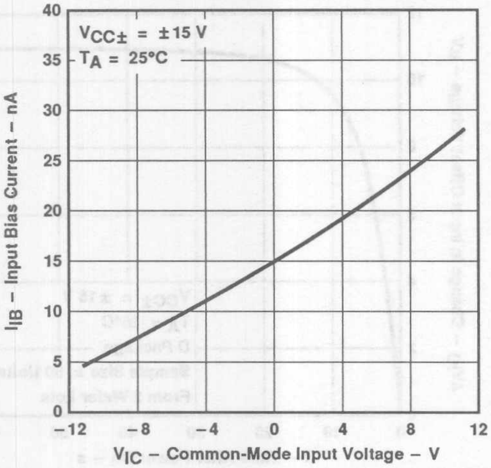

Figure 10

INPUT BIAS CURRENT
vs
FREE-AIR TEMPERATURE

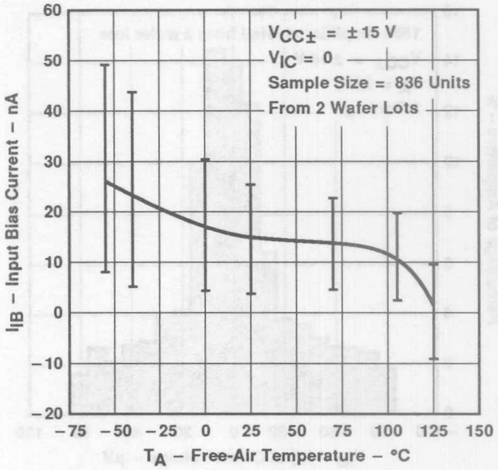

Figure 11

INPUT CURRENT
vs
DIFFERENTIAL INPUT VOLTAGE

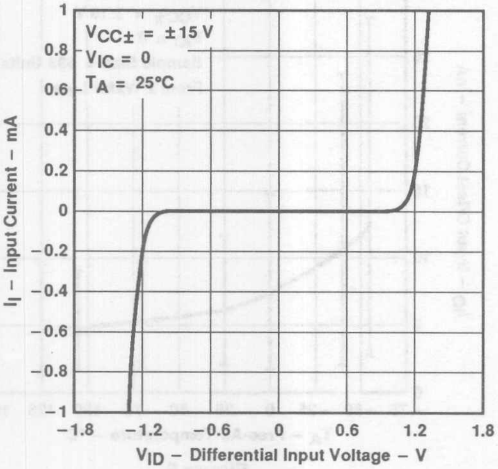

Figure 12

MAXIMUM PEAK-TO-PEAK
OUTPUT VOLTAGE
vs
FREQUENCY

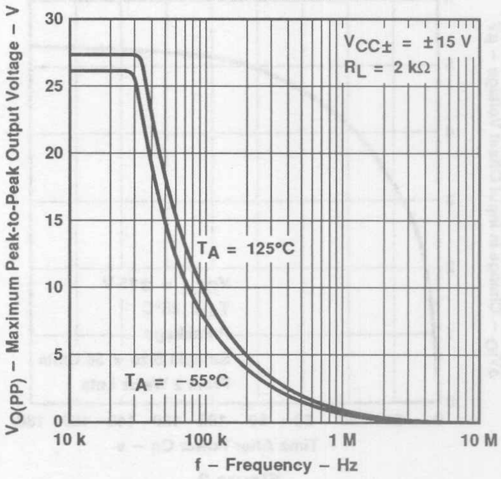

Figure 13

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†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

**MAXIMUM POSITIVE PEAK
OUTPUT VOLTAGE
vs
LOAD RESISTANCE**

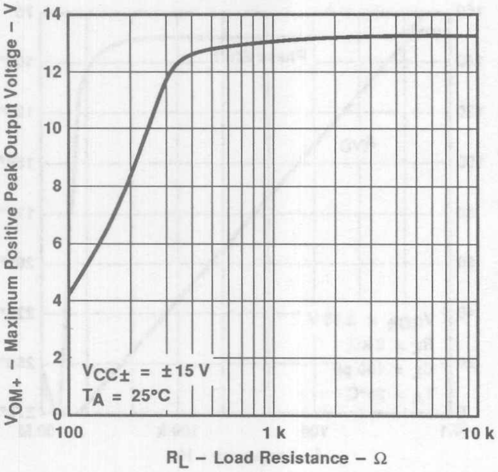

Figure 14

**MAXIMUM NEGATIVE PEAK
OUTPUT VOLTAGE
vs
LOAD RESISTANCE**

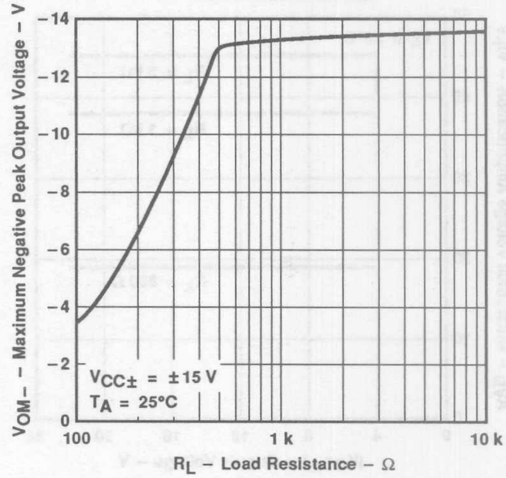

Figure 15

**MAXIMUM POSITIVE PEAK
OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE**

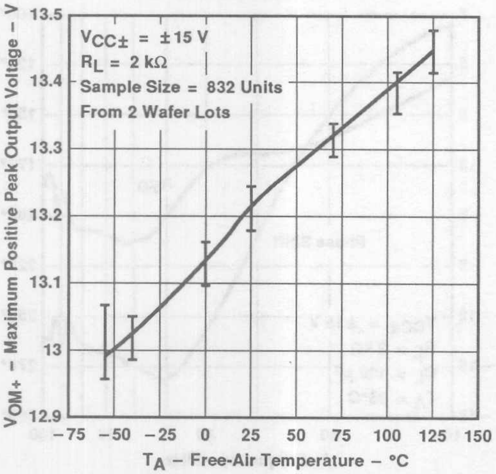

Figure 16

**MAXIMUM NEGATIVE PEAK
OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE**

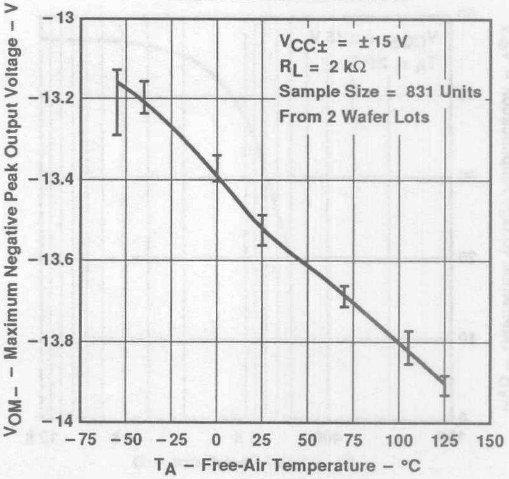

Figure 17

---

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS

**LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION vs SUPPLY VOLTAGE**

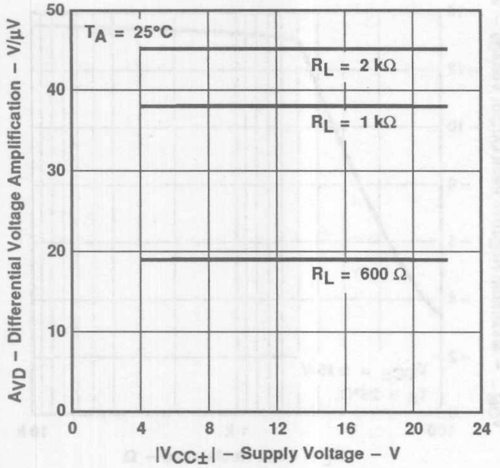

Figure 18

**LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT vs FREQUENCY**

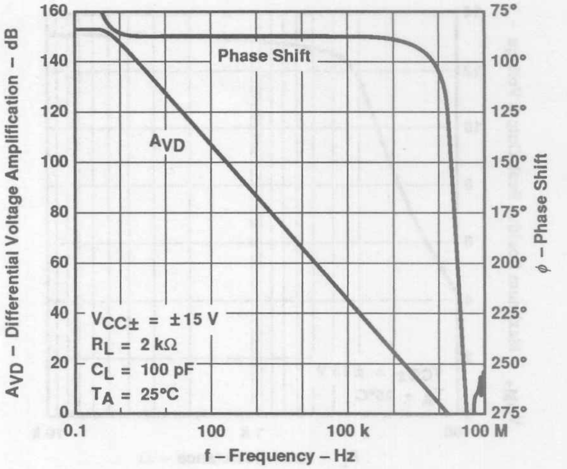

Figure 19

**LARGE-SIGNAL VOLTAGE AMPLIFICATION vs LOAD RESISTANCE**

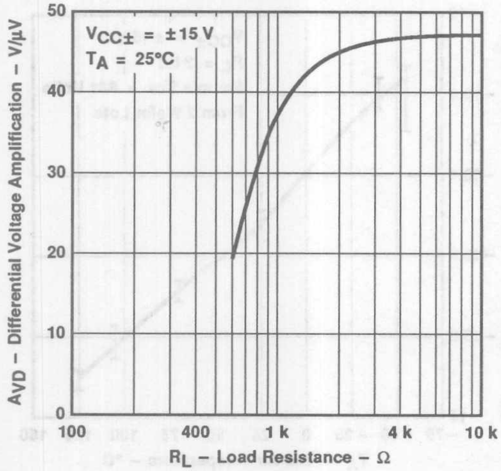

Figure 20

**LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT vs FREQUENCY**

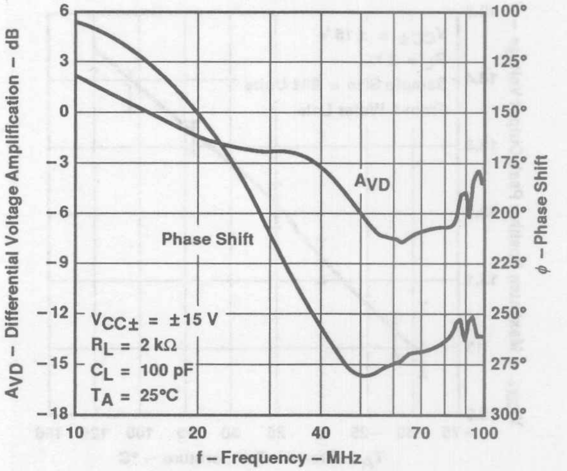

Figure 21

## TYPICAL CHARACTERISTICS†

### LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION vs FREE-AIR TEMPERATURE

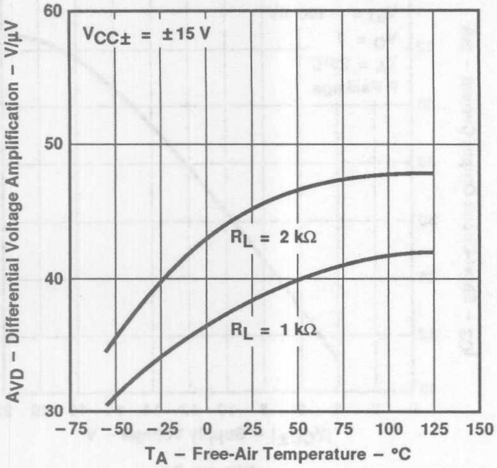

Figure 22

### OUTPUT IMPEDANCE vs FREQUENCY

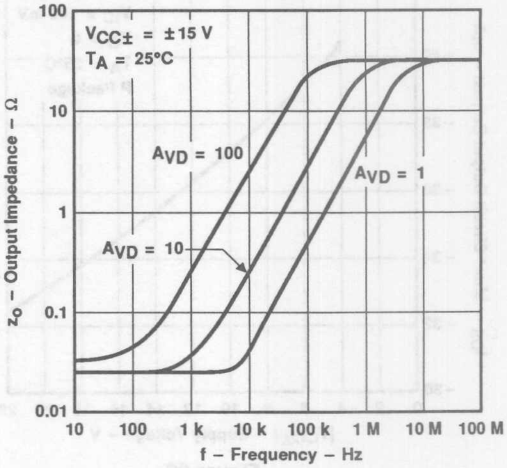

Figure 23

### COMMON-MODE REJECTION RATIO vs FREQUENCY

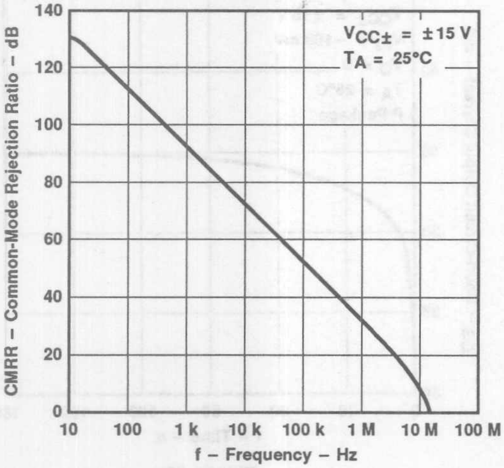

Figure 24

### SUPPLY VOLTAGE REJECTION RATIO vs FREQUENCY

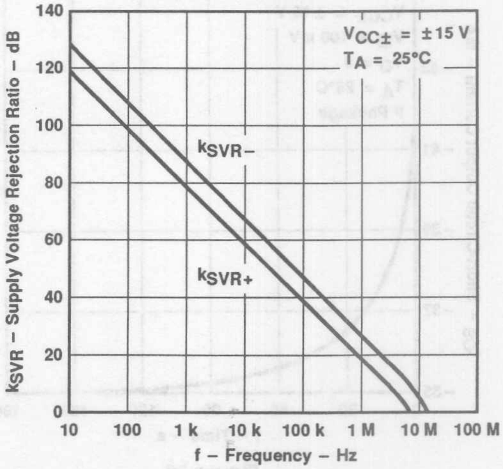

Figure 25

---

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS

SHORT-CIRCUIT OUTPUT CURRENT
vs
SUPPLY VOLTAGE

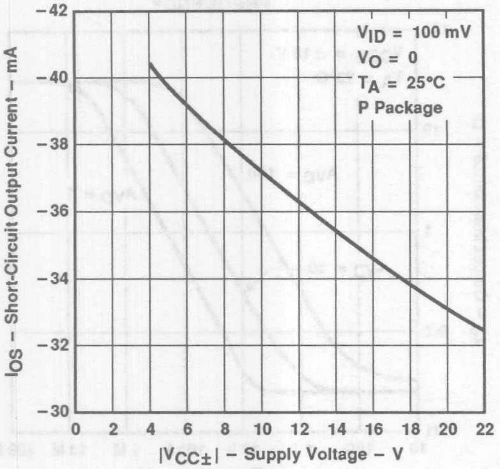

Figure 26

SHORT-CIRCUIT OUTPUT CURRENT
vs
SUPPLY VOLTAGE

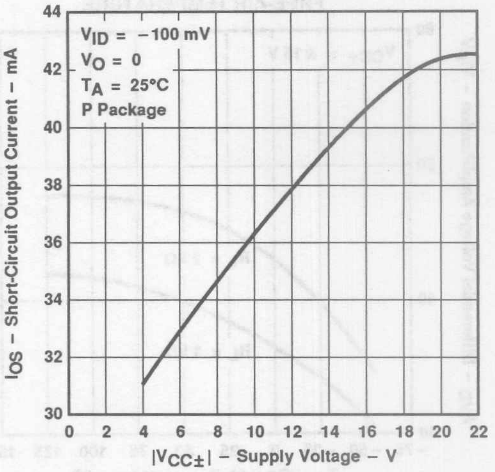

Figure 27

SHORT-CIRCUIT OUTPUT CURRENT
vs
ELAPSED TIME

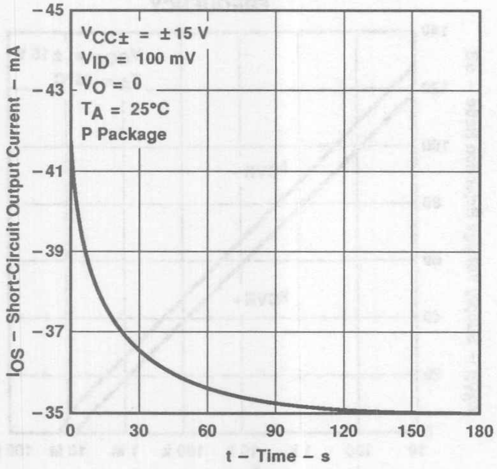

Figure 28

SHORT-CIRCUIT OUTPUT CURRENT
vs
ELAPSED TIME

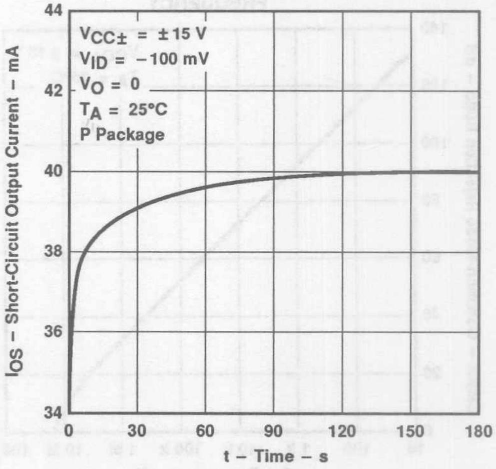

Figure 29

## TYPICAL CHARACTERISTICS[†]

**SHORT-CIRCUIT OUTPUT CURRENT
vs
FREE-AIR TEMPERATURE**

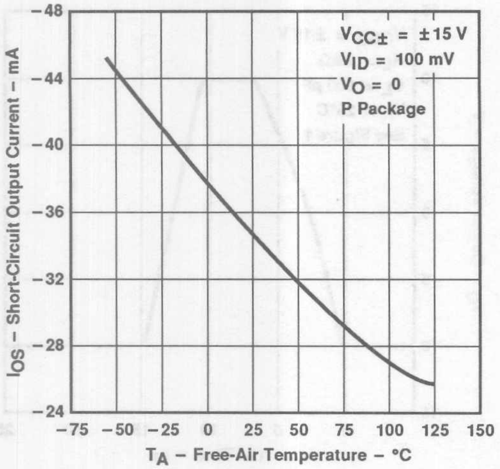

Figure 30

**SHORT-CIRCUIT OUTPUT CURRENT
vs
FREE-AIR TEMPERATURE**

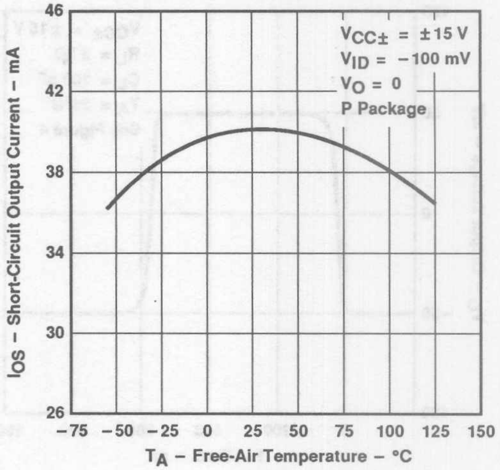

Figure 31

**SUPPLY CURRENT
vs
SUPPLY VOLTAGE**

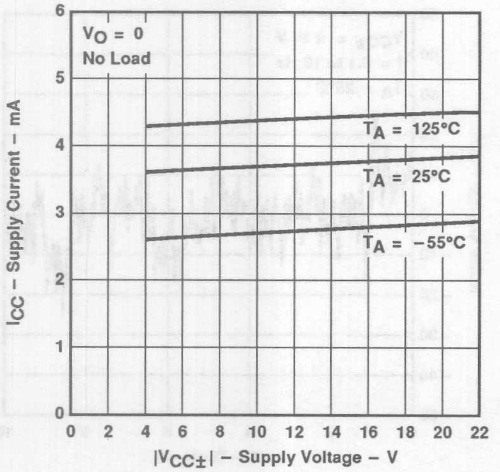

Figure 32

**SUPPLY CURRENT
vs
FREE-AIR TEMPERATURE**

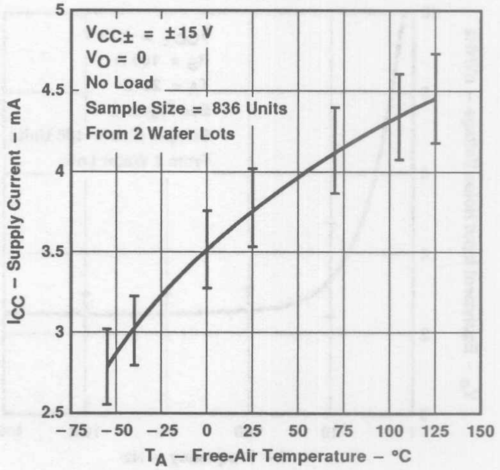

Figure 33

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[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS

### VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE

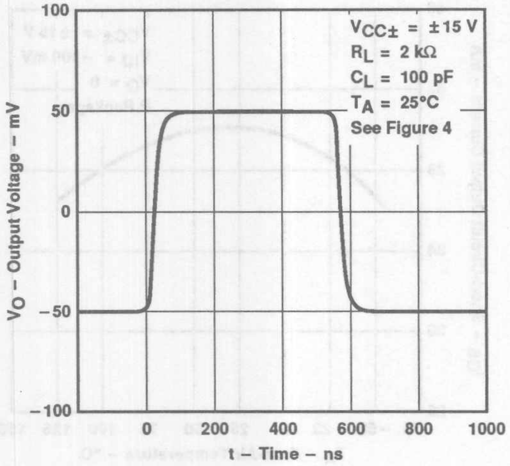

Figure 34

### VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSE

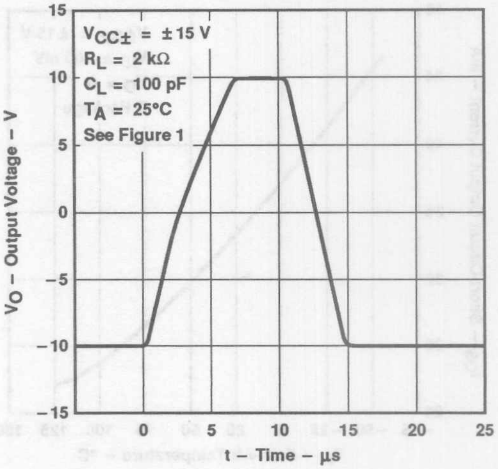

Figure 35

### EQUIVALENT INPUT NOISE VOLTAGE vs FREQUENCY

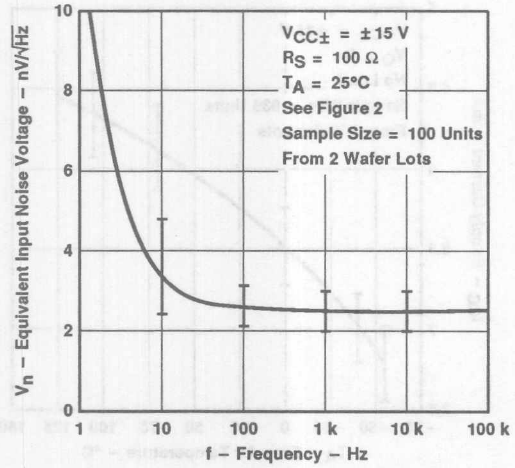

Figure 36

### NOISE VOLTAGE (REFERRED TO INPUT) OVER A 10-SECOND INTERVAL

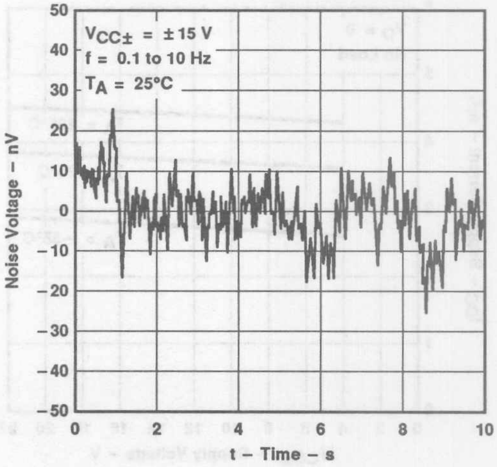

Figure 37

## TYPICAL CHARACTERISTICS†

### UNITY-GAIN BANDWIDTH vs SUPPLY VOLTAGE

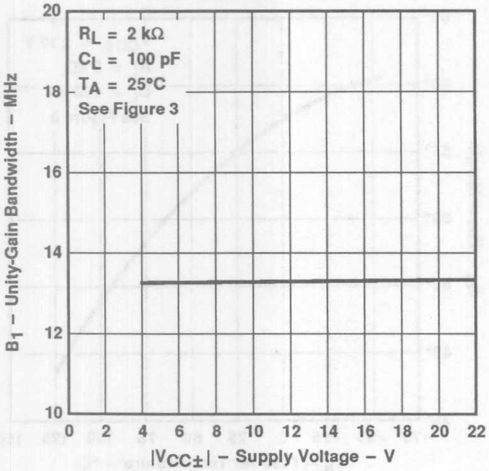

Figure 38

### UNITY-GAIN BANDWIDTH vs LOAD CAPACITANCE

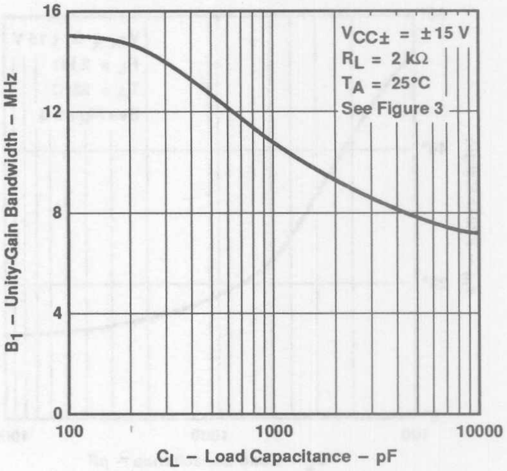

Figure 39

### SLEW RATE vs FREE-AIR TEMPERATURE

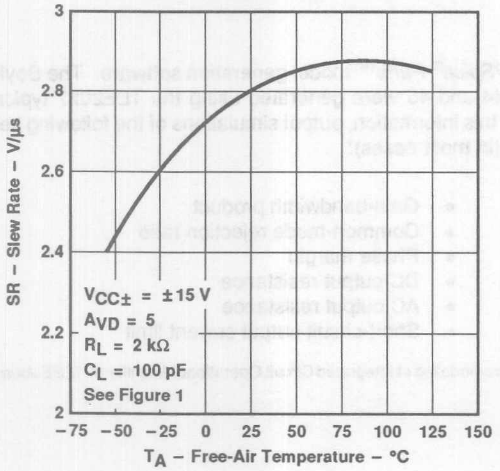

Figure 40

### PHASE MARGIN vs SUPPLY VOLTAGE

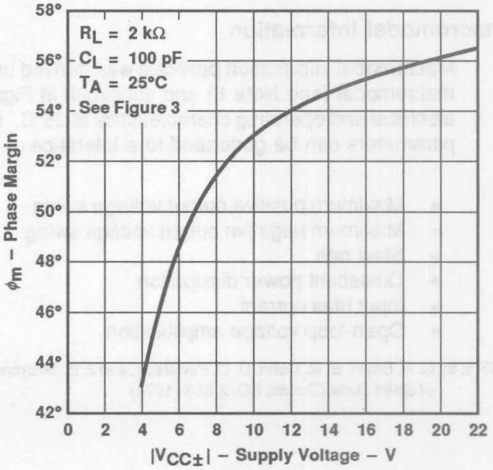

Figure 41

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† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

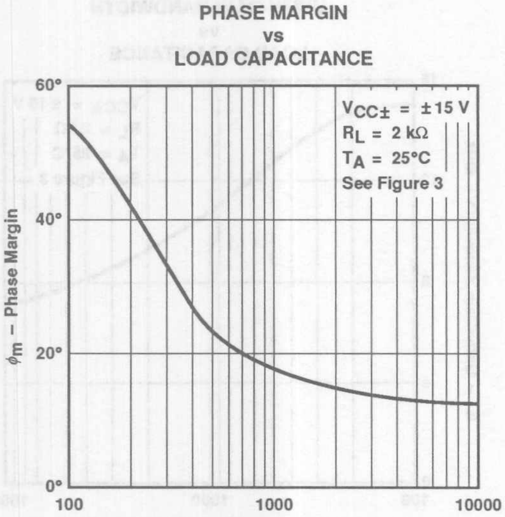


Figure 42

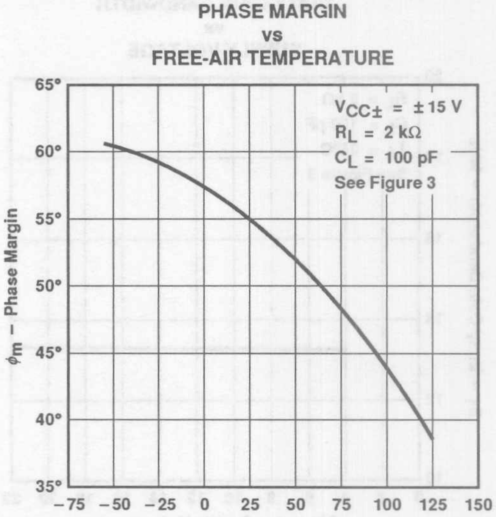


Figure 43

---

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## APPLICATION INFORMATION

### macromodel information

Macromodel information provided was derived using *PSpice® Parts™* model generation software. The Boyle macromodel (see Note 6) and subcircuit in Figures 44 and 45 were generated using the TLE2027 typical electrical and operating characteristics at 25°C. Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

- Maximum positive output voltage swing
- Maximum negative output voltage swing
- Slew rate
- Quiescent power dissipation
- Input bias current
- Open-loop voltage amplification
- Gain-bandwidth product
- Common-mode rejection ratio
- Phase margin
- DC output resistance
- AC output resistance
- Short-circuit output current limit

NOTE 6: G. R. Boyle, B. M. Cohn, D. O. Pederson, and J. E. Solomon, "Macromodeling of Integrated Circuit Operational Amplifiers", *IEEE Journal of Solid-State Circuits*, SC-9, 353 (1974).

*PSpice* is a registered trademark of MicroSim Corporation.
*Parts* is a trademark of MicroSim Corporation.

**Macromodels, simulation models, or other models provided by TI, directly or indirectly, are not warranted by TI as fully representing all of the specifications and operating characteristics of the semiconductor product to which the model relates.**

## APPLICATION INFORMATION

### macromodel information (continued)

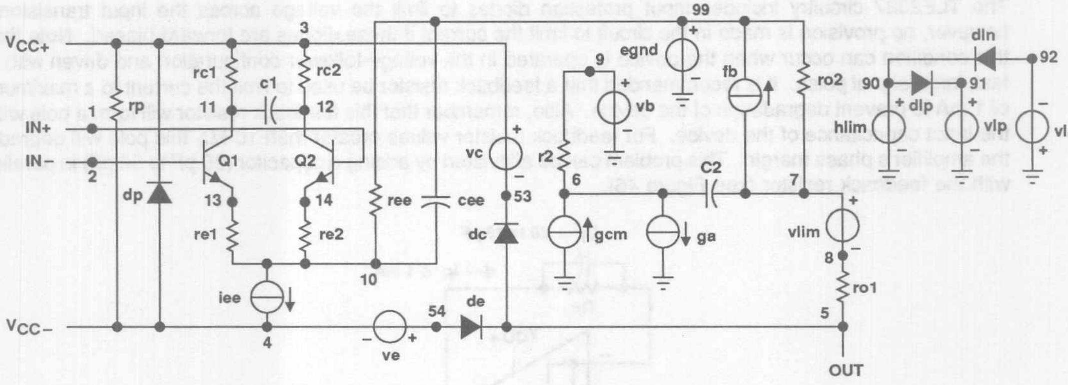


Figure 44. Boyle Macromodel

```
.subckt TLE2027  1 2 3 4 5
*
  c1   11 12 4.003E-12
  c2    6  7 20.00E-12
  dc    5 53 dx
  de   54  5 dx
  dlp  90 91 dx
  dln  92 90 dx
  dp    4  3 dx
  egnd 99  0 poly(2) (3,0) (4,0) 0 .5 .5
  fb    7 99 poly(5) vb vc ve vlp vln 0 954.8E6 -1E9 1E9 1E9 -1E9
  ga    6  0 11 12 2.062E-3
  gcm   0  6 10 99 531.3E-12
  iee  10  4 dc 56.01E-6
  hlim 90  0 vlim 1K
  q1   11  2 13 qx
  q2   12  1 14 qx
  r2    6  9 100.0E3
  rc1   3 11 530.5
  rc2   3 12 530.5
  re1  13 10 -393.2
  re2  14 10 -393.2
  ree  10 99 3.571E6
  ro1   8  5 25
  ro2   7 99 25
  rp    3  4 8.013E3
  vb    9  0 dc 0
  vc    3 53 dc 2.400
  ve   54. 4 dc 2.100
  vlim  7  8 dc 0
  vlp  91  0 dc 40
  vln   0 92 dc 40
.model dx D(Is=800.0E-18)
.model qx NPN(Is=800.0E-18 Bf=7.000E3)
.ends
```

Figure 45. Macromodel Subcircuit

## APPLICATION INFORMATION

### voltage-follower applications

The TLE2027 circuitry includes input protection diodes to limit the voltage across the input transistors; however, no provision is made in the circuit to limit the current if these diodes are forward-biased. Note that this condition can occur when the device is operated in the voltage-follower configuration and driven with a fast, large-signal pulse. It is recommended that a feedback resistor be used to limit the current to a maximum of 1 mA to prevent degradation of the device. Also, remember that this feedback resistor will form a pole with the input capacitance of the device. For feedback resistor values greater than 10 kΩ, this pole will degrade the amplifier's phase margin. This problem can be alleviated by adding a capacitor (20 pF to 50 pF) in parallel with the feedback resistor (see Figure 46).

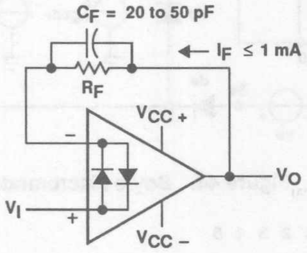
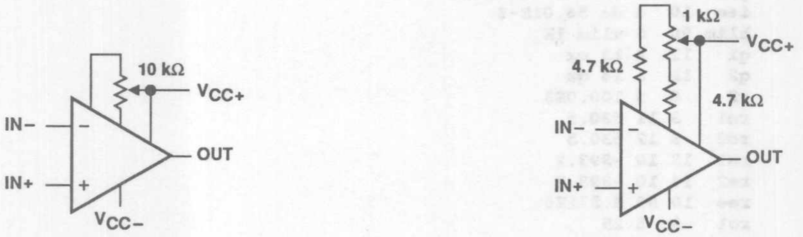


Figure 46. Voltage-Follower

### input offset voltage nulling

The TLE2027 series offers external null pins that can be used to further reduce the input offset voltage. The circuits of Figure 47 can be connected as shown if the feature is desired. If external nulling is not needed, the null pins may be left disconnected.



(a) Standard Adjustment

(b) Adjustment with Improved Sensitivity

Figure 47. Input Offset Voltage Nulling Circuits

# TLE2037, TLE2037A
# EXCALIBUR LOW-NOISE HIGH-SPEED PRECISION DECOMPENSATED OPERATIONAL AMPLIFIERS

D3454, MAY 1990 – REVISED APRIL 1991

## available features

- **Outstanding Combination of DC Precision and AC Performance:**
  **Gain-Bandwidth Product . . . 80 MHz Typ**
  **V . . . 3.3 nV/√Hz at f = 10 Hz Typ,**
  **2.5 nV/√Hz at f = 1 kHz Typ**
  **$V_{IO}$ . . . 25 µV Max**
  **$A_{VD}$ . . . 45 V/µV Typ, With $R_L$ = 2 kΩ,**
  **19 V/µV Typ, With $R_L$ = 600 Ω**
- **Available in Standard-Pinout Small-Outline Package**
- **Output Features Saturation Recovery Circuitry**
- **Macromodels and Statistical Information Included**

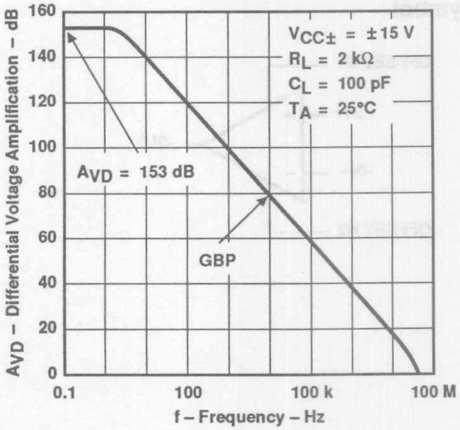
## description

The TLE2037 and TLE2037A combine innovative circuit design expertise and high-quality process control techniques to produce a level of ac performance and dc precision previously unavailable in single operational amplifiers. Using the Texas Instruments state-of-the-art Excalibur process, these devices allow upgrades to systems that use lower-precision devices.

The TLE2037 and TLE2037A are decompensated versions of the TLE2027 and TLE2027A and are stable to a close-loop gain of 5. In the area of dc precision, these parts offer maximum offset voltages of 100 µV and 25 µV, respectively, common-mode rejection ratio of 131 dB (typ), supply voltage rejection ratio of 144 dB (typ), and dc gain of 45 V/µV (typ).

The ac performance is highlighted by a typical gain-bandwidth product specification of 80 MHz, 50° of phase margin, and noise voltage specifications of 3.3 nV/√Hz and 2.5 nV/√Hz at frequencies of 10 Hz and 1 kHz, respectively.

LARGE-SIGNAL
DIFFERENTIAL VOLTAGE AMPLIFICATION
vs
FREQUENCY



Both the TLE2037 and TLE2037A are available in a wide variety of packages, including the industry-standard 8-pin small-outline version for high-density system applications. The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from –40°C to 105°C. The M-suffix devices are characterized for operation over the full military temperature range of –55°C to 125°C.

**AVAILABLE OPTIONS**

| $T_A$ | $V_{IO}$ max AT 25°C | PACKAGE | | | | |
|---|---|---|---|---|---|---|
| | | SMALL-OUTLINE (D) | CHIP CARRIER (FK) | CERAMIC DIP (JG) | METAL CAN (L) | PLASTIC DIP (P) |
| 0°C to 70°C | 25 µV | TLE2037ACD | — | — | — | TLE2037ACP |
| | 100 µV | TLE2037CD | — | — | — | TLE2037CP |
| – 40°C to 105°C | 25 µV | TLE2037AID | — | — | — | TLE2037AIP |
| | 100 µV | TLE2037ID | — | — | — | TLE2037IP |
| – 55°C to 125°C | 25 µV | TLE2037AMD | TLE2037AMFK | TLE2037AMJG | TLE2037AML | TLE2037AMP |
| | 100 µV | TLE2037MD | TLE2037MFK | TLE2037MJG | TLE2037ML | TLE2037MP |

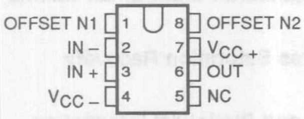
D packages are available taped and reeled. Add "R" suffix to device type, (e.g., TLE2037ACDR).

PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

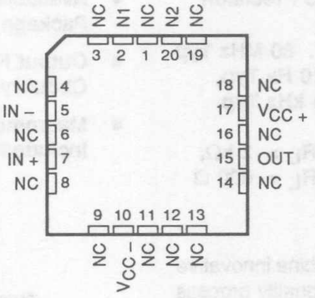
TEXAS INSTRUMENTS

Copyright © 1991, Texas Instruments Incorporated
On products compliant to MIL-STD-883, Class B, all parameters are tested unless otherwise noted. On all other products, production processing does not necessarily include testing of all parameters.

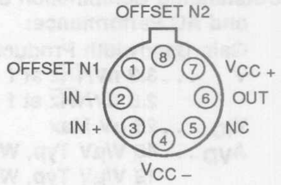
D, JG, OR P PACKAGE
(TOP VIEW)



FK PACKAGE
(TOP VIEW)



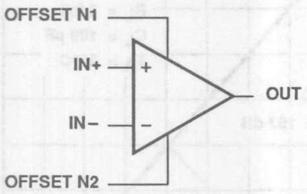
L PACKAGE
(TOP VIEW)



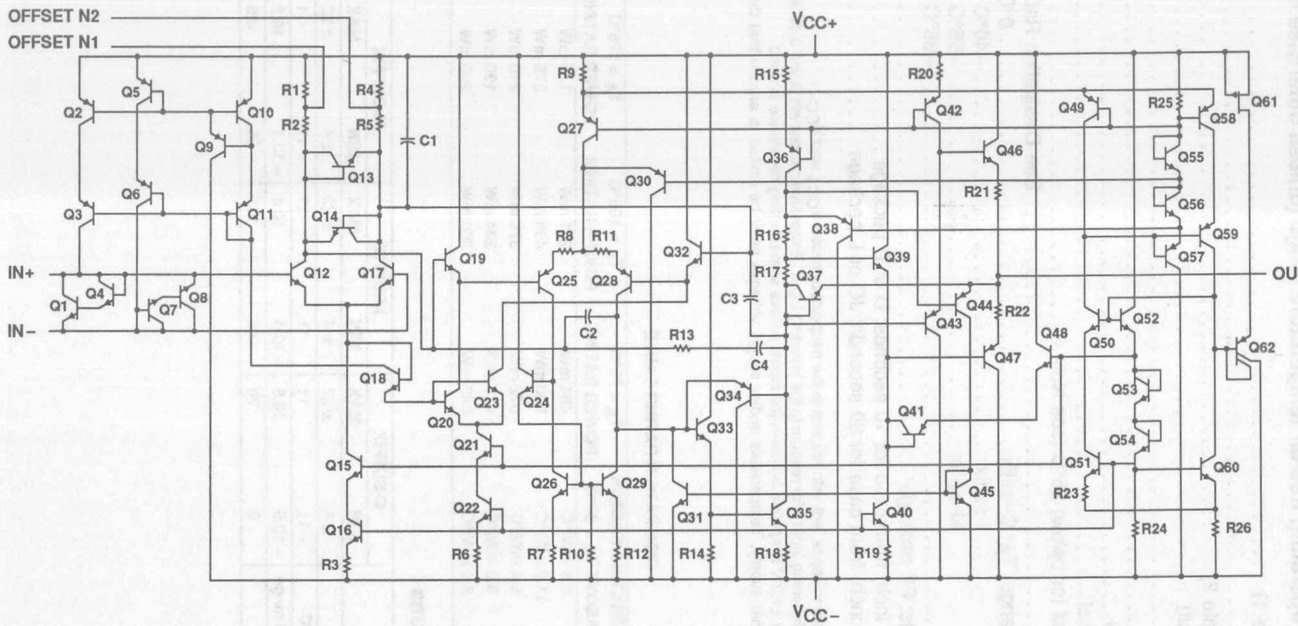
Pin 4 of the L package is in electrical contact with the case.

NC – No internal connection

## symbol



## equivalent schematic



## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|---|
| Supply voltage, $V_{CC+}$ (see Note 1) | 22 V |
| Supply voltage, $V_{CC-}$ | −22 V |
| Differential input voltage (see Note 2) | ±1.2 V |
| Input voltage range, $V_I$ (any input) | $V_{CC\pm}$ |
| Input current, $I_I$ (each input) | ±1 mA |
| Output current, $I_O$ | ±50 mA |
| Total current into $V_{CC+}$ terminal | 50 mA |
| Total current out of $V_{CC-}$ terminal | 50 mA |
| Duration of short-circuit current at (or below) 25°C (see Note 3) | unlimited |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range, $T_A$: C-suffix | 0°C to 70°C |
| I-suffix | −40°C to 105°C |
| M-suffix | −55°C to 125°C |
| Storage temperature range | −65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG or L package | 300°C |

NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between $V_{CC+}$ and $V_{CC-}$.

2. Differential voltages are at the noninverting input with respect to the inverting input. Excessive current will flow if a differential input voltage in excess of approximately ±1.2 V is applied between the inputs unless some limiting resistance is used.

3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25°C$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25°C$ | $T_A = 70°C$ POWER RATING | $T_A = 105°C$ POWER RATING | $T_A = 125°C$ POWER RATING |
|---|---|---|---|---|---|
| D | 725 mW | 5.8 mW/°C | 464 mW | 261 mW | 145 mW |
| FK | 1375 mW | 11.0 mW/°C | 880 mW | 495 mW | 275 mW |
| JG | 1050 mW | 8.4 mW/°C | 672 mW | 378 mW | 210 mW |
| L | 650 mW | 5.2 mW/°C | 416 mW | 234 mW | 130 mW |
| P | 1000 mW | 8.0 mW/°C | 640 mW | 360 mW | 200 mW |

## recommended operating conditions

| | | C-SUFFIX | | I-SUFFIX | | M-SUFFIX | | UNIT |
|---|---|---|---|---|---|---|---|---|
| | | MIN | MAX | MIN | MAX | MIN | MAX | |
| Supply voltage, $V_{CC\pm}$ | | ± 4 | ± 22 | ± 4 | ± 22 | ± 4 | ± 22 | V |
| Common-mode input voltage, $V_{IC}$ | $T_A$ = 25°C | − 11 | 11 | − 11 | 11 | − 11 | 11 | V |
| | $T_A$ = Full range | − 10.5 | 10.5 | − 10.4 | 10.4 | − 10.2 | 10.2 | |
| Operating free-air temperature, $T_A$ | | 0 | 70 | − 40 | 105 | − 55 | 125 | °C |

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2037C | | | TLE2037AC | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 20 | 100 | | 10 | 25 | µV |
| | | | Full range | | | 145 | | | 70 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 0.4 | 1 | | 0.2 | 1 | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.006 | 1 | | 0.006 | 1 | µV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 6 | 90 | | 6 | 90 | nA |
| | | | Full range | | | 150 | | | 150 | |
| $I_{IB}$ | Input bias current | | 25°C | | 15 | 90 | | 15 | 90 | nA |
| | | | Full range | | | 150 | | | 150 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | 25°C | − 11 to 11 | − 13 to 13 | | − 11 to 11 | − 13 to 13 | | V |
| | | | Full range | − 10.5 to 10.5 | | | − 10.5 to 10.5 | | | |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $R_L = 600\ \Omega$ | 25°C | 10.5 | 12.9 | | 10.5 | 12.9 | | V |
| | | | Full range | 10 | | | 10 | | | |
| | | $R_L = 2\ k\Omega$ | 25°C | 12 | 13.2 | | 12 | 13.2 | | |
| | | | Full range | 11 | | | 11 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | $R_L = 600\ \Omega$ | 25°C | − 10.5 | − 13 | | − 10.5 | − 13 | | V |
| | | | Full range | − 10 | | | − 10 | | | |
| | | $R_L = 2\ k\Omega$ | 25°C | − 12 | − 13.5 | | − 12 | − 13.5 | | |
| | | | Full range | − 11 | | | − 11 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = \pm 11$ V, $R_L = 2\ k\Omega$ | 25°C | 5 | 45 | | 10 | 45 | | V/µV |
| | | $V_O = \pm 10$ V, $R_L = 2\ k\Omega$ | Full range | 2 | | | 4 | | | |
| | | $V_O = \pm 10$ V, $R_L = 1\ k\Omega$ | 25°C | 3.5 | 38 | | 8 | 38 | | |
| | | | Full range | 1 | | | 2.5 | | | |
| | | $V_O = \pm 10$ V, $R_L = 600\ \Omega$ | 25°C | 2 | 19 | | 5 | 19 | | |
| | | | Full range | 0.5 | | | 2 | | | |
| $c_i$ | Input capacitance | | 25°C | | 8 | | | 8 | | pF |
| $z_o$ | Open-loop output impedance | $I_O = 0$ | 25°C | | 50 | | | 50 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 25°C | 100 | 131 | | 117 | 131 | | dB |
| | | | Full range | 98 | | | 114 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 4$ V to $\pm 18$ V, $R_S = 50\ \Omega$ | 25°C | 94 | 144 | | 110 | 144 | | dB |
| | | $V_{CC\pm} = \pm 4$ V to $\pm 18$ V, $R_S = 50\ \Omega$ | Full range | 92 | | | 106 | | | |
| $I_{CC}$ | Supply current | $V_O = 0$, No Load | 25°C | | 3.8 | 5.3 | | 3.8 | 4.7 | mA |
| | | | Full range | | | 5.6 | | | 4.8 | |

†Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150$°C extrapolated to $T_A = 25$°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V

| | PARAMETER | TEST CONDITIONS | $T_A$† | TLE2037C | | | TLE2037AC | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate | $A_{VD} = 5$, $R_L = 2\ k\Omega$,<br>$C_L = 100$ pF, See Figure 1 | 25°C | 6 | 7.5 | | 6 | 7.5 | | V/µs |
| | | | Full range | 5 | | | 5 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | $R_S = 100\ \Omega$, f = 10 Hz | 25°C | | 3.3 | 8 | | 3.3 | 4.5 | nV/√Hz |
| | | $R_S = 100\ \Omega$, f = 1 kHz | | | 2.5 | 4.5 | | 2.5 | 3.8 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | 25°C | | 50 | 250 | | 50 | 130 | nV |
| $I_n$ | Equivalent input noise current | f = 10 Hz | 25°C | | 1.5 | 4 | | 1.5 | 4 | pA/√Hz |
| | | f = 1 kHz | | | 0.4 | 0.6 | | 0.4 | 0.6 | |
| THD | Total harmonic distortion | $V_O = \pm 10$ V, $A_{VD} = 5$,<br>See Note 5 | 25°C | | < 0.002% | | | < 0.002% | | |
| | Gain-bandwidth product | f = 100 kHz, $R_L = 2\ k\Omega$,<br>$C_L = 100$ pF | 25°C | 50 | 76 | | 50 | 76 | | MHz |
| $B_{OM}$ | Maximum output-swing bandwidth | $R_L = 2\ k\Omega$ | 25°C | | 80 | | | 80 | | kHz |
| $\phi_m$ | Phase margin | $R_L = 2\ k\Omega$, $C_L = 100$ pF | 25°C | | 50° | | | 50° | | |

†Full range is 0°C to 70°C.

NOTE 5: Measured distortion of the source used in the analysis was 0.002%.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2037I | | | TLE2037AI | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 20 | 100 | | 10 | 25 | µV |
| | | | Full range | | | 180 | | | 105 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 0.4 | 1 | | 0.2 | 1 | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.006 | 1 | | 0.006 | 1 | µV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 6 | 90 | | 6 | 90 | nA |
| | | | Full range | | | 150 | | | 150 | |
| $I_{IB}$ | Input bias current | | 25°C | | 15 | 90 | | 15 | 90 | nA |
| | | | Full range | | | 150 | | | 150 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | 25°C | − 11<br>to<br>11 | − 13<br>to<br>13 | | − 11<br>to<br>11 | − 13<br>to<br>13 | | V |
| | | | Full range | − 10.4<br>to<br>10.4 | | | − 10.4<br>to<br>10.4 | | | |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $R_L = 600\ \Omega$ | 25°C | 10.5 | 12.9 | | 10.5 | 12.9 | | V |
| | | | Full range | 10 | | | 10 | | | |
| | | $R_L = 2\ k\Omega$ | 25°C | 12 | 13.2 | | 12 | 13.2 | | |
| | | | Full range | 11 | | | 11 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | $R_L = 600\ \Omega$ | 25°C | − 10.5 | − 13 | | − 10.5 | − 13 | | V |
| | | | Full range | − 10 | | | − 10 | | | |
| | | $R_L = 2\ k\Omega$ | 25°C | − 12 | − 13.5 | | − 12 | − 13.5 | | |
| | | | Full range | − 11 | | | − 11 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = \pm 11$ V, $R_L = 2\ k\Omega$ | 25°C | 5 | 45 | | 10 | 45 | | V/µV |
| | | $V_O = \pm 10$ V, $R_L = 2\ k\Omega$ | Full range | 2.5 | | | 3.5 | | | |
| | | $V_O = \pm 10$ V, $R_L = 1\ k\Omega$ | 25°C | 3.5 | 38 | | 8 | 38 | | |
| | | | Full range | 1.8 | | | 2.2 | | | |
| | | $V_O = \pm 10$ V, $R_L = 600\ \Omega$ | 25°C | 2 | 19 | | 5 | 19 | | |
| | | | Full range | 0.5 | | | 1.1 | | | |
| $c_i$ | Input capacitance | | 25°C | | 8 | | | 8 | | pF |
| $z_o$ | Open-loop output impedance | $I_O = 0$ | 25°C | | 50 | | | 50 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min,<br>$R_S = 50\ \Omega$ | 25°C | 100 | 131 | | 117 | 131 | | dB |
| | | | Full range | 96 | | | 113 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 4$ V to $\pm 18$ V,<br>$R_S = 50\ \Omega$ | 25°C | 94 | 144 | | 110 | 144 | | dB |
| | | $V_{CC\pm} = \pm 4$ V to $\pm 18$ V,<br>$R_S = 50\ \Omega$ | Full range | 90 | | | 105 | | | |
| $I_{CC}$ | Supply current | $V_O = 0$, No Load | 25°C | | 3.8 | 5.3 | | 3.8 | 4.7 | mA |
| | | | Full range | | | 5.6 | | | 4.9 | |

†Full range is −40°C to 105°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2037I | | | TLE2037AI | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate | $A_{VD} = 5$, $R_L = 2$ kΩ,<br>$C_L = 100$ pF, See Figure 1 | 25°C | 6 | 7.5 | | 6 | 7.5 | | V/μs |
| | | | Full range | 4.7 | | | 4.7 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | $R_S = 100$ Ω, f = 10 Hz | 25°C | | 3.3 | 8 | | 3.3 | 4.5 | nV/√Hz |
| | | $R_S = 100$ Ω, f = 1 kHz | | | 2.5 | 4.5 | | 2.5 | 3.8 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | 25°C | | 50 | 250 | | 50 | 130 | nV |
| $I_n$ | Equivalent input noise current | f = 10 Hz | 25°C | | 1.5 | 4 | | 1.5 | 4 | pA/√Hz |
| | | f = 1 kHz | | | 0.4 | 0.6 | | 0.4 | 0.6 | |
| THD | Total harmonic distortion | $V_O = \pm 10$ V, $A_{VD} = 5$,<br>See Note 5 | 25°C | | < 0.002% | | | < 0.002% | | |
| | Gain-bandwidth product | f = 100 kHz, $R_L = 2$ kΩ,<br>$C_L = 100$ pF | 25°C | 50 | 76 | | 50 | 76 | | MHz |
| $B_{OM}$ | Maximum output-swing bandwidth | $R_L = 2$ kΩ | 25°C | | 80 | | | 80 | | kHz |
| $\phi_m$ | Phase margin | $R_L = 2$ kΩ, $C_L = 100$ pF | 25°C | | 50° | | | 50° | | |

†Full range is – 40°C to 105°C.

NOTE 5: Measured distortion of the source used in the analysis was 0.002%.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2037M | | | TLE2037AM | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 20 | 100 | | 10 | 25 | µV |
| | | | Full range | | | 200 | | | 105 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 0.4 | 1* | | 0.2 | 1* | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.006 | 1 | | 0.006 | 1 | µV/mo |
| $I_{IO}$ | Input offset current | | 25°C | | 6 | 90 | | 6 | 90 | nA |
| | | | Full range | | | 150 | | | 150 | |
| $I_{IB}$ | Input bias current | | 25°C | | 15 | 90 | | 15 | 90 | nA |
| | | | Full range | | | 150 | | | 150 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | 25°C | − 11 to 11 | − 13 to 13 | | − 11 to 11 | − 13 to 13 | | V |
| | | | Full range | − 10.3 to 10.3 | | | − 10.4 to 10.4 | | | |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $R_L = 600\ \Omega$ | 25°C | 10.5 | 12.9 | | 10.5 | 12.9 | | V |
| | | | Full range | 10 | | | 10 | | | |
| | | $R_L = 2\ k\Omega$ | 25°C | 12 | 13.2 | | 12 | 13.2 | | |
| | | | Full range | 11 | | | 11 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | $R_L = 600\ \Omega$ | 25°C | − 10.5 | − 13 | | − 10.5 | − 13 | | V |
| | | | Full range | − 10 | | | − 10 | | | |
| | | $R_L = 2\ k\Omega$ | 25°C | − 12 | − 13.5 | | − 12 | − 13.5 | | |
| | | | Full range | − 11 | | | − 11 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = \pm 11$ V, $R_L = 2\ k\Omega$ | 25°C | 5 | 45 | | 10 | 45 | | V/µV |
| | | $V_O = \pm 10$ V, $R_L = 2\ k\Omega$ | Full range | 2.5 | | | 3.5 | | | |
| | | $V_O = \pm 10$ V, $R_L = 1\ k\Omega$ | 25°C | 3.5 | 38 | | 8 | 38 | | |
| | | | Full range | 1.8 | | | 2.2 | | | |
| | | $V_O = \pm 10$ V, $R_L = 600\ \Omega$ | 25°C | 2 | 19 | | 5 | 19 | | |
| $c_i$ | Input capacitance | | 25°C | | 8 | | | 8 | | pF |
| $z_o$ | Open-loop output impedance | $I_O = 0$ | 25°C | | 50 | | | 50 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 25°C | 100 | 131 | | 117 | 131 | | dB |
| | | | Full range | 96 | | | 113 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 4$ V to $\pm 18$ V, $R_S = 50\ \Omega$ | 25°C | 94 | 144 | | 110 | 144 | | dB |
| | | $V_{CC\pm} = \pm 4$ V to $\pm 18$ V, $R_S = 50\ \Omega$ | Full range | 90 | | | 105 | | | |
| $I_{CC}$ | Supply current | $V_O = 0$, No Load | 25°C | | 3.8 | 5.3 | | 3.8 | 4.7 | mA |
| | | | Full range | | | 5.6 | | | 5 | |

*On products compliant to MIL-STD-883, Class B, this parameter is not production tested.

†Full range is −55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V

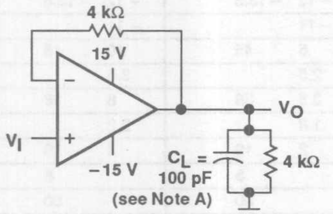
| | PARAMETER | TEST CONDITIONS | $T_A$† | TLE2037M MIN | TLE2037M TYP | TLE2037M MAX | TLE2037AM MIN | TLE2037AM TYP | TLE2037AM MAX | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| SR | Slew rate | $A_{VD} = 5$, $R_L = 2$ kΩ, | 25°C | 6* | 7.5 | | 6* | 7.5 | | V/μs |
| | | $C_L = 100$ pF, See Figure 1 | Full range | 4.4* | | | 4.4* | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | $R_S = 100$ Ω, f = 10 Hz | 25°C | | 3.3 | 8* | | 3.3 | 4.5* | nV/√Hz |
| | | $R_S = 100$ Ω, f = 1 kHz | | | 2.5 | 4.5* | | 2.5 | 3.8* | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | 25°C | | 50 | 250* | | 50 | 130* | nV |
| $I_n$ | Equivalent input noise current | f = 10 Hz | 25°C | | 1.5 | 4* | | 1.5 | 4* | pA/√Hz |
| | | f = 1 kHz | | | 0.4 | 0.6* | | 0.4 | 0.6* | |
| THD | Total harmonic distortion | $V_O = \pm 10$ V, $A_{VD} = 5$, See Note 5 | 25°C | | < 0.002% | | | < 0.002% | | |
| | Gain-bandwidth product | f = 100 kHz, $R_L = 2$ kΩ, $C_L = 100$ pF | 25°C | 50 | 76 | | 50 | 76 | | MHz |
| $B_{OM}$ | Maximum output-swing bandwidth | $R_L = 2$ kΩ | 25°C | | 80 | | | 80 | | kHz |
| $\phi_m$ | Phase margin | $R_L = 2$ kΩ, $C_L = 100$ pF | 25°C | | 50° | | | 50° | | |

*On products compliant to MIL-STD-883, Class B, this parameter is not production tested.

†Full range is – 55°C to 125°C.

NOTE 5: Measured distortion of the source used in the analysis was 0.002%.

## PARAMETER MEASUREMENT INFORMATION



NOTE A: $C_L$ includes fixture capacitance.

Figure 1. Slew Rate Test Circuit

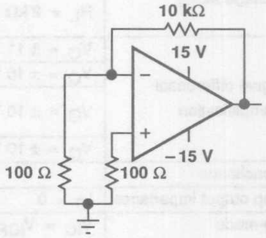


Figure 2. Noise Voltage Test Circuit

## PARAMETER MEASUREMENT INFORMATION

### typical values

Typical values as presented in this data sheet represent the median (50% point) of device parametric performance.

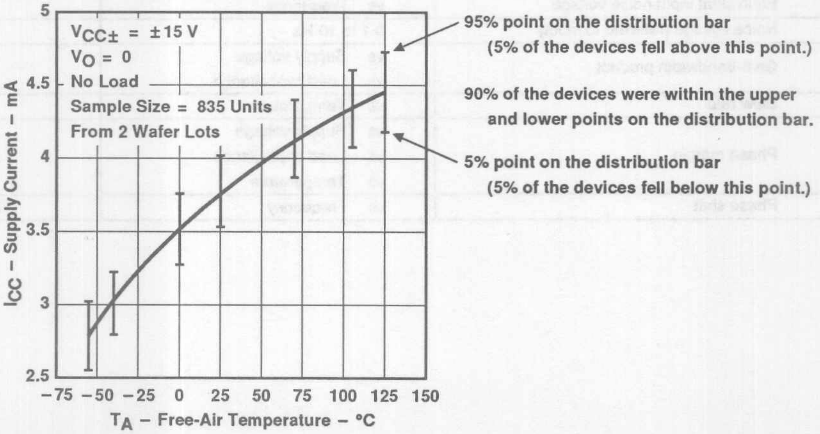
### initial estimates of parameter distributions

In the on-going program of improving data sheets and supplying more information to our customer, Texas Instruments has added an estimate of not only the "typical" values but also the spread around these values. These are in the form of distribution bars that show the 95% (upper) points and the 5% (lower) points from our characterization of the initial wafer lots of this new device type (see Figure 3). The distribution bars are shown at the points where data was actually collected. The 95% and 5% points are used instead of ±3 sigma since some of the distributions are not true Gaussian distributions.

The number of units tested and the number of different wafer lots used are on all of the graphs where distribution bars are shown. As noted in Figure 3, there were a total of 835 units from 2 wafer lots. In this case, there is a very good estimate for the within-lot variability and a possibly poor estimate of the lot-to-lot variability. This will always be the case on newly released products, since there will only be data available from a few wafer lots.

The distribution bars are not intended to replace the minimum and maximum limits in the electrical tables. Each distribution bar represents 90% of the total units tested at a specific temperature. And, while 10% of the units tested fell outside any given distribution bar, this should not be interpreted to mean that the same individual devices fell outside every distribution bar.

SUPPLY CURRENT
vs
FREE-AIR TEMPERATURE



95% point on the distribution bar
(5% of the devices fell above this point.)

90% of the devices were within the upper and lower points on the distribution bar.

5% point on the distribution bar
(5% of the devices fell below this point.)

Figure 3. Sample Graph with Distribution Bars

## TYPICAL CHARACTERISTICS

### table of graphs

| | | | FIGURE |
|---|---|---|---|
| $V_{IO}$ | Input offset voltage | Distribution | 4 |
| $\Delta V_{IO}$ | Input offset voltage change | vs Time after power on | 5, 6 |
| $I_{IO}$ | Input offset current | vs Temperature | 7 |
| $I_{IB}$ | Input bias current | vs Common-mode input voltage<br>vs Temperature | 8<br>9 |
| $I_I$ | Input current | vs Differential input voltage | 10 |
| $V_{O(PP)}$ | Maximum peak-to-peak output voltage | vs Frequency | 11 |
| $V_{OM}$ | Maximum peak output voltage | vs Load resistance<br>vs Temperature | 12, 13<br>14, 15 |
| $A_{VD}$ | Large-signal differential voltage amplification | vs Supply voltage<br>vs Load resistance<br>vs Frequency<br>vs Temperature | 16<br>18<br>17, 19<br>20 |
| $z_o$ | Output impedance | vs Frequency | 21 |
| CMRR | Common-mode rejection ratio | vs Frequency | 22 |
| $k_{SVR}$ | Supply voltage rejection ratio | vs Frequency | 23 |
| $I_{OS}$ | Short-circuit output current | vs Supply voltage<br>vs Time<br>vs Temperature | 24, 25<br>26, 27<br>28, 29 |
| $I_{CC}$ | Supply current | vs Supply voltage<br>vs Temperature | 30<br>31 |
| | Pulse response | Small-signal<br>Large-signal | 32<br>33 |
| $V_n$ | Equivalent input noise voltage | vs Frequency | 34 |
| | Noise voltage (referred to input) | 0.1 to 10 Hz | 35 |
| | Gain-bandwidth product | vs Supply voltage<br>vs Load capacitance | 36<br>37 |
| SR | Slew rate | vs Temperature | 38 |
| $\phi_m$ | Phase margin | vs Supply voltage<br>vs Load capacitance<br>vs Temperature | 39<br>40<br>41 |
| $\phi$ | Phase shift | vs Frequency | 17, 19 |

## TYPICAL CHARACTERISTICS†

TLE2037
DISTRIBUTION OF
INPUT OFFSET VOLTAGE

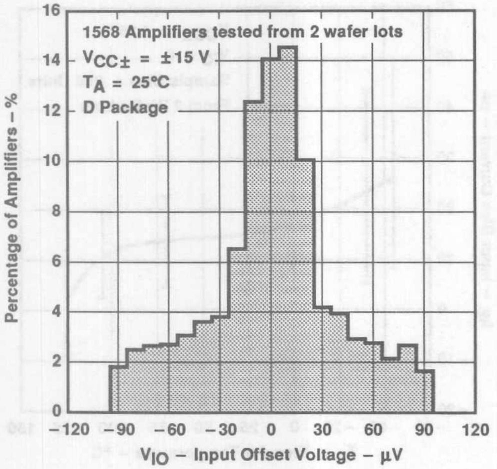


Figure 4

INPUT OFFSET VOLTAGE CHANGE
vs
TIME AFTER POWER ON

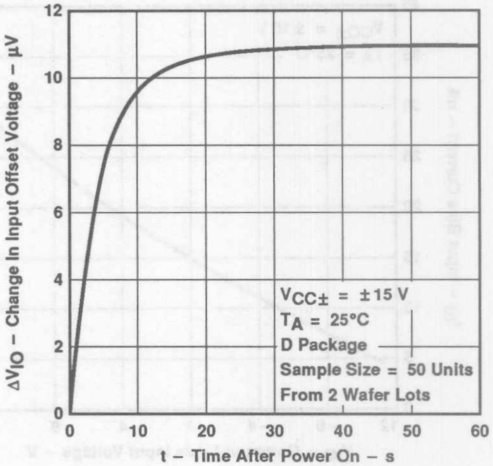


Figure 5

INPUT OFFSET VOLTAGE CHANGE
vs
TIME AFTER POWER ON

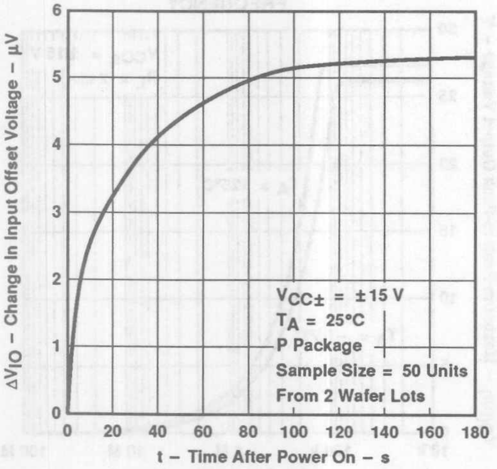


Figure 6

INPUT OFFSET CURRENT
vs
FREE-AIR TEMPERATURE

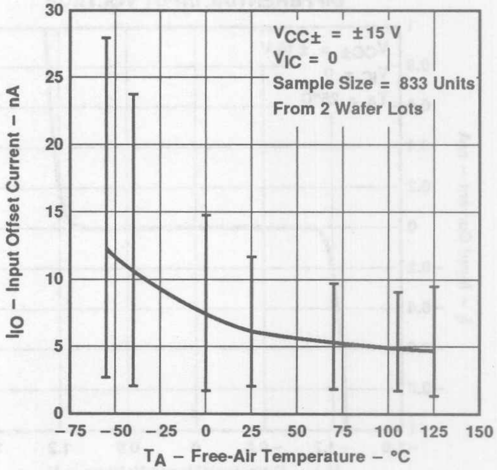


Figure 7

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† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS[†]

INPUT BIAS CURRENT
vs
COMMON-MODE INPUT VOLTAGE

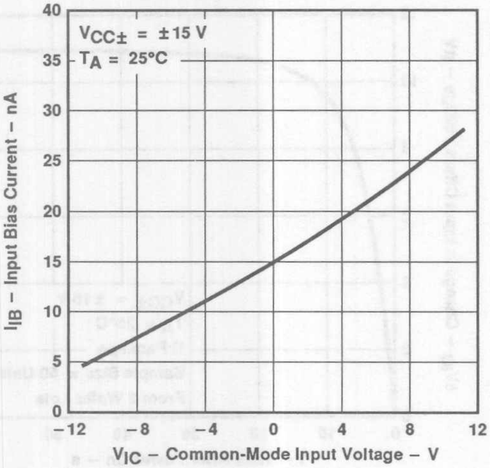

Figure 8

INPUT BIAS CURRENT
vs
FREE-AIR TEMPERATURE

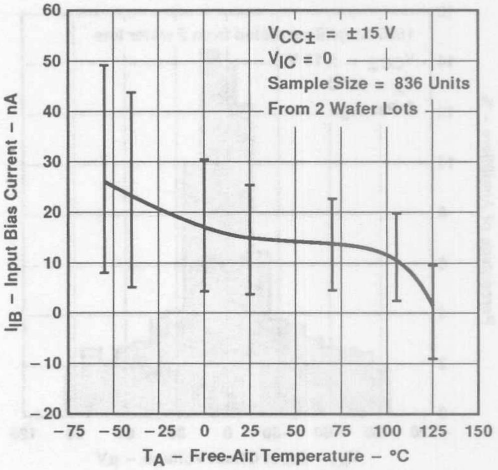

Figure 9

INPUT CURRENT
vs
DIFFERENTIAL INPUT VOLTAGE

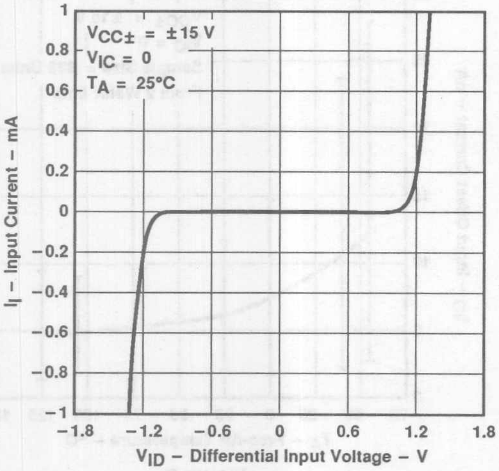

Figure 10

MAXIMUM PEAK-TO-PEAK
OUTPUT VOLTAGE
vs
FREQUENCY

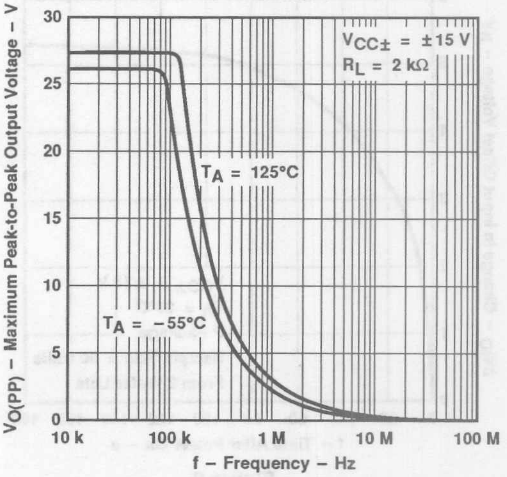

Figure 11

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[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS[†]

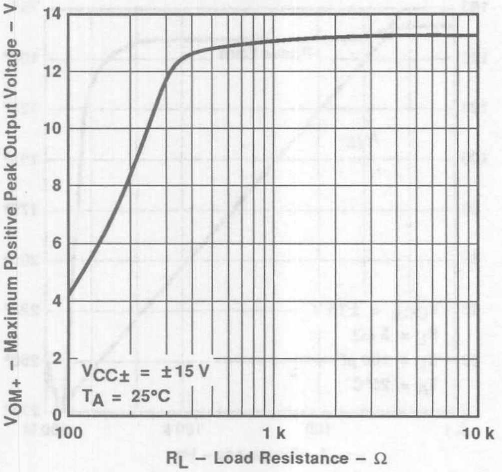

MAXIMUM POSITIVE PEAK OUTPUT VOLTAGE vs LOAD RESISTANCE

Figure 12

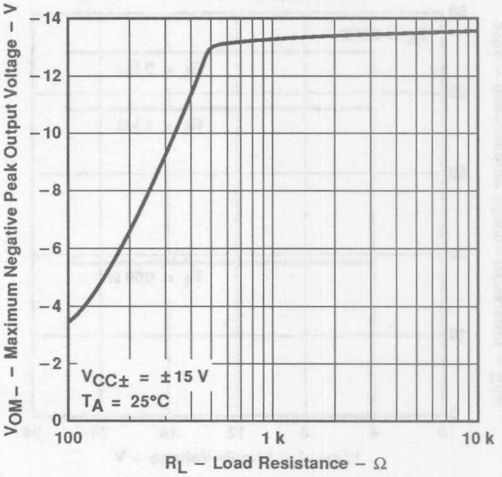

MAXIMUM NEGATIVE PEAK OUTPUT VOLTAGE vs LOAD RESISTANCE

Figure 13

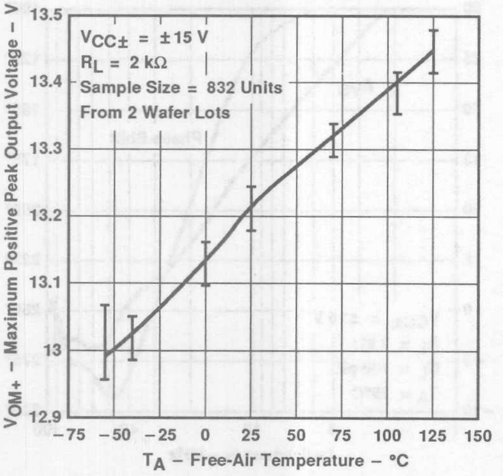

MAXIMUM POSITIVE PEAK OUTPUT VOLTAGE vs FREE-AIR TEMPERATURE

Figure 14

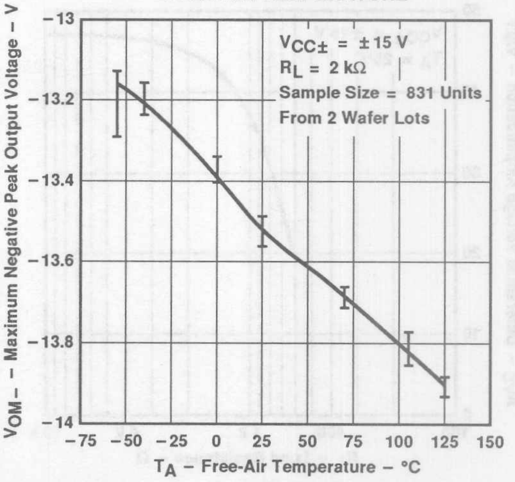
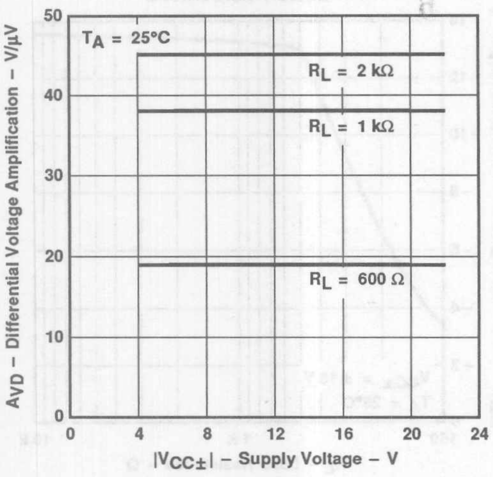

MAXIMUM NEGATIVE PEAK OUTPUT VOLTAGE vs FREE-AIR TEMPERATURE

Figure 15

---

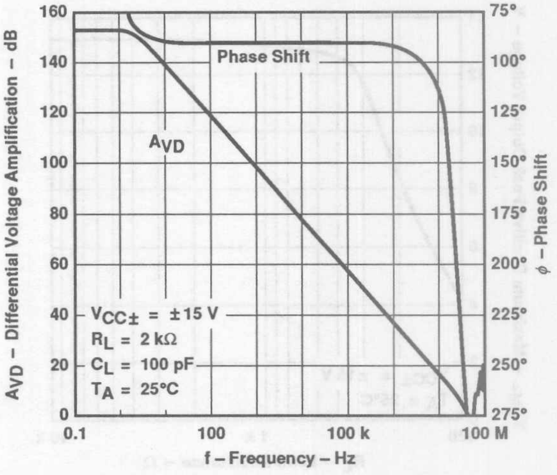
[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS



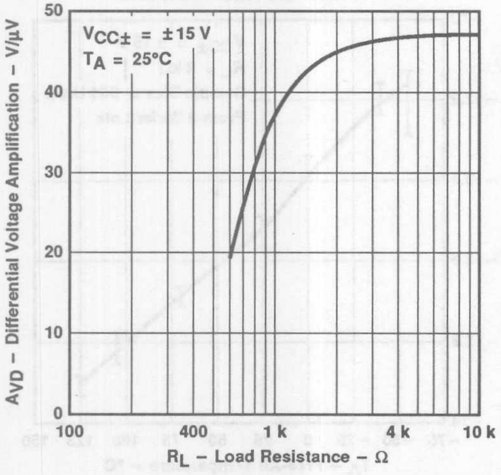
LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION vs SUPPLY VOLTAGE

Figure 16



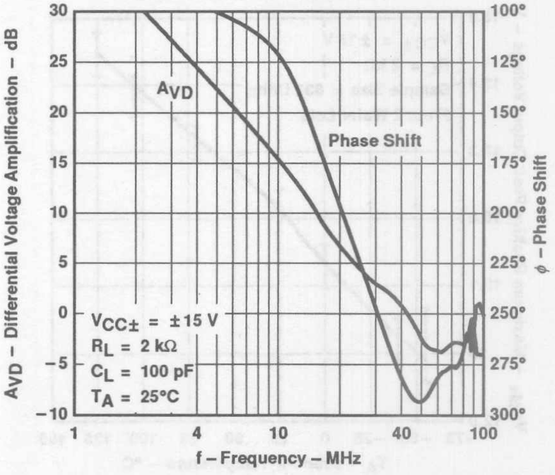
LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT vs FREQUENCY

Figure 17



LARGE-SIGNAL VOLTAGE AMPLIFICATION vs LOAD RESISTANCE

Figure 18



LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT vs FREQUENCY

Figure 19

## TYPICAL CHARACTERISTICS†

### LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION vs FREE-AIR TEMPERATURE

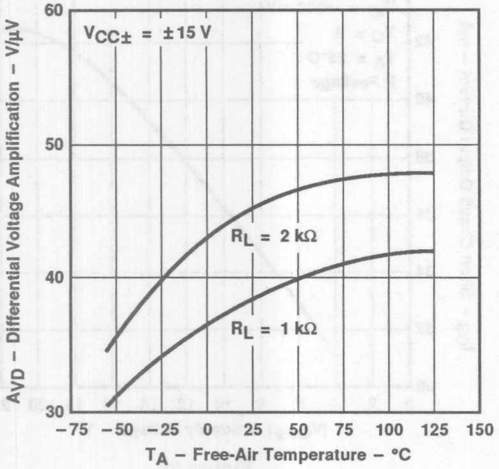


Figure 20

### OUTPUT IMPEDANCE vs FREQUENCY

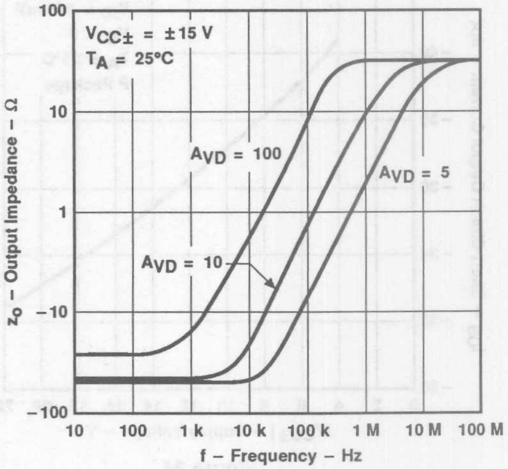


Figure 21

### COMMON-MODE REJECTION RATIO vs FREQUENCY

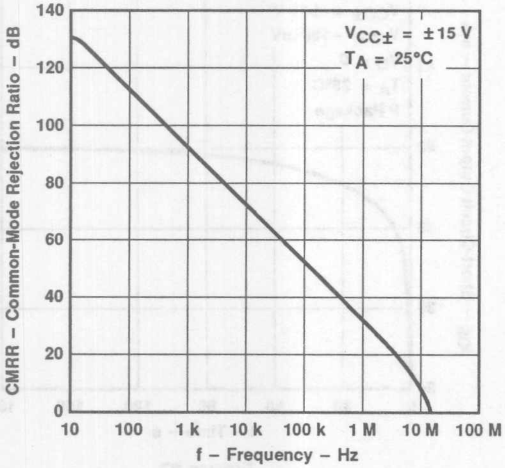


Figure 22

### SUPPLY VOLTAGE REJECTION RATIO vs FREQUENCY

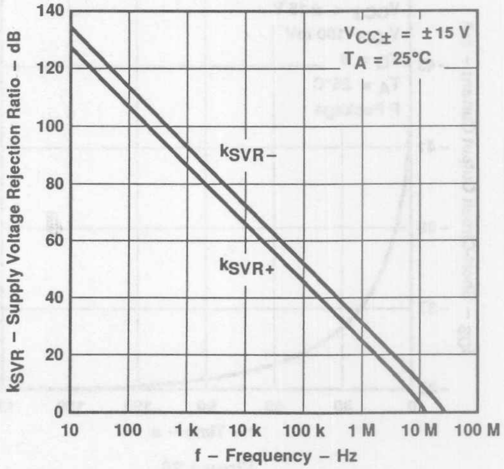


Figure 23

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† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS

### SHORT-CIRCUIT OUTPUT CURRENT vs SUPPLY VOLTAGE

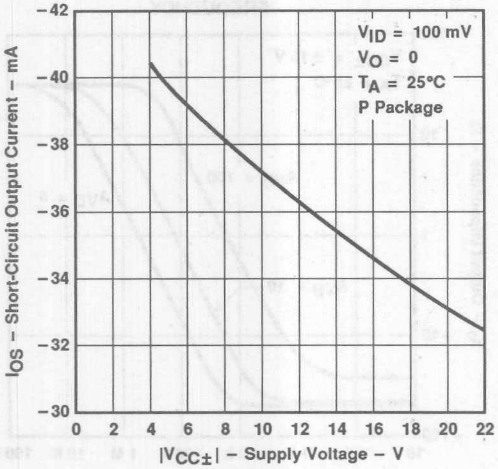


Figure 24

### SHORT-CIRCUIT OUTPUT CURRENT vs SUPPLY VOLTAGE

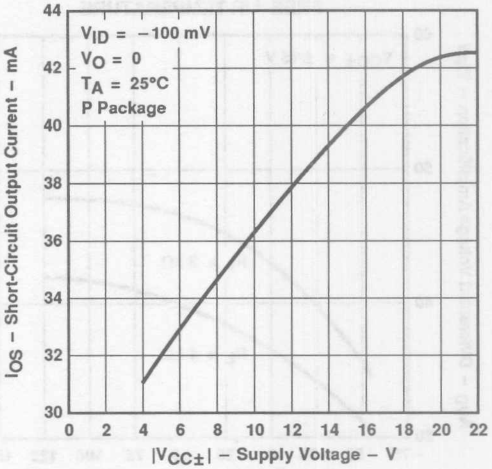


Figure 25

### SHORT-CIRCUIT OUTPUT CURRENT vs ELAPSED TIME

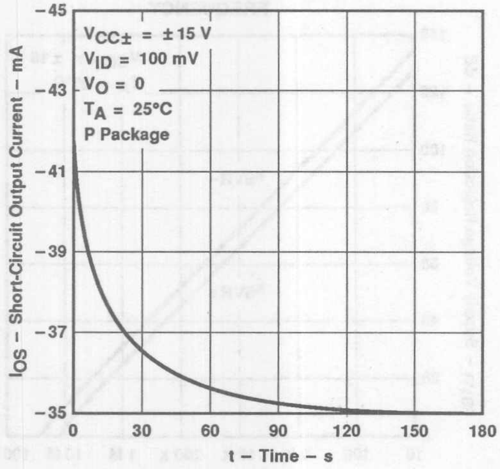


Figure 26

### SHORT-CIRCUIT OUTPUT CURRENT vs ELAPSED TIME

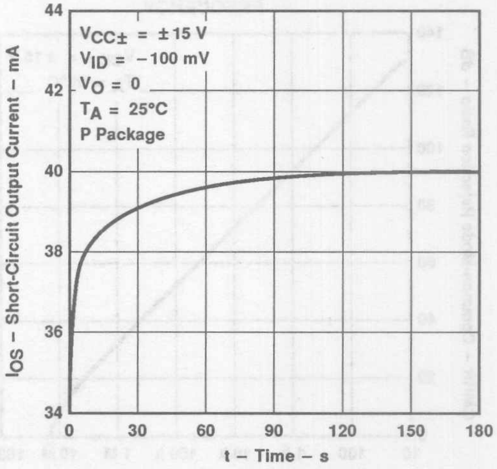


Figure 27

## TYPICAL CHARACTERISTICS†

### SHORT-CIRCUIT OUTPUT CURRENT vs FREE-AIR TEMPERATURE

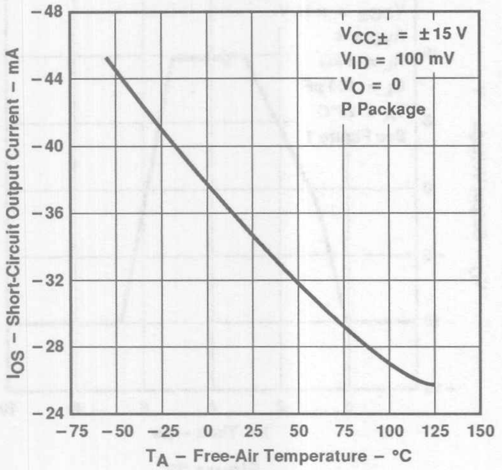


Figure 28

### SHORT-CIRCUIT OUTPUT CURRENT vs FREE-AIR TEMPERATURE

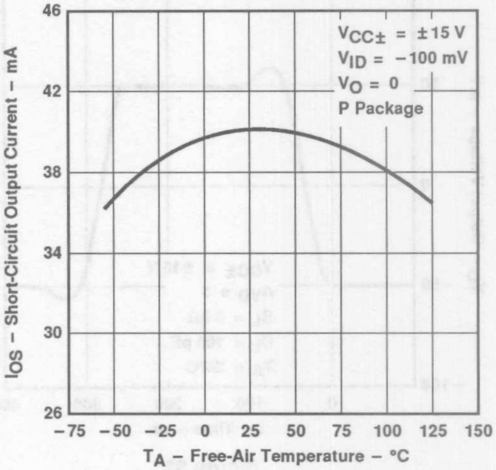


Figure 29

### SUPPLY CURRENT vs SUPPLY VOLTAGE

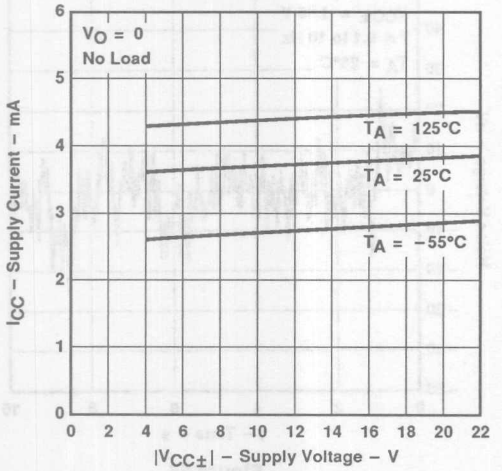


Figure 30

### SUPPLY CURRENT vs FREE-AIR TEMPERATURE

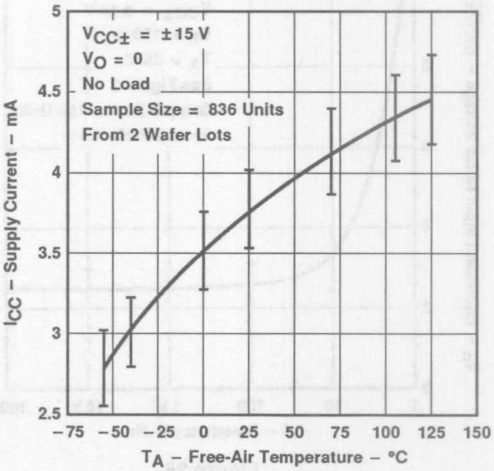


Figure 31

---

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS

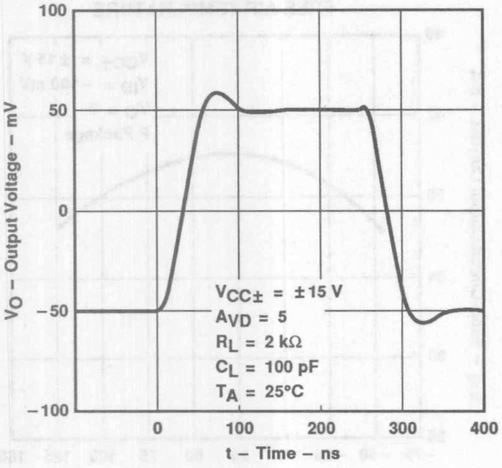

SMALL-SIGNAL
PULSE RESPONSE

Figure 32

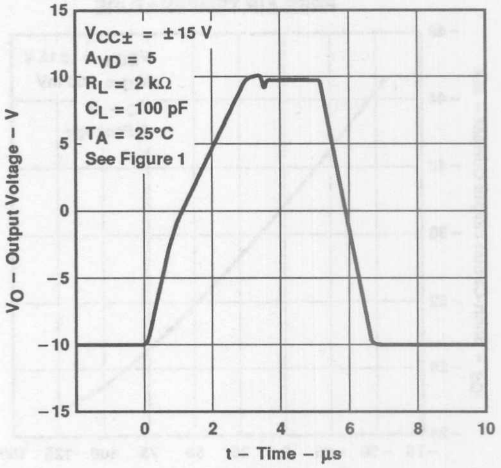

LARGE-SIGNAL
PULSE RESPONSE

Figure 33

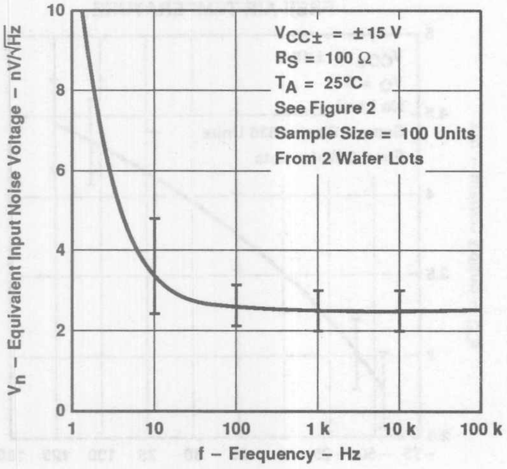

EQUIVALENT INPUT NOISE VOLTAGE
vs
FREQUENCY

Figure 34

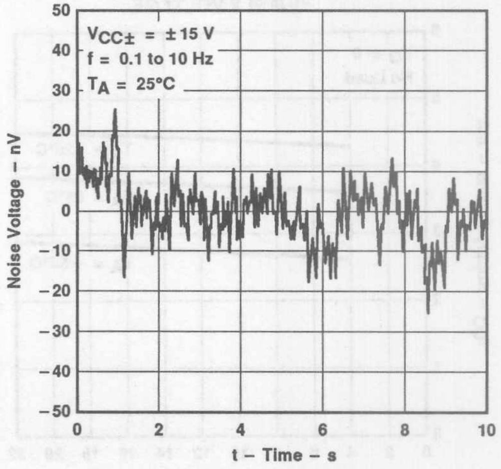

NOISE VOLTAGE
(REFERRED TO INPUT)
OVER A 10-SECOND INTERVAL

Figure 35

## TYPICAL CHARACTERISTICS†

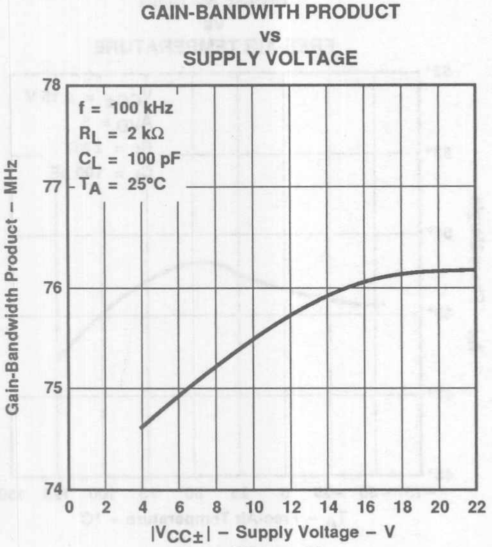

GAIN-BANDWITH PRODUCT
vs
SUPPLY VOLTAGE

Figure 36

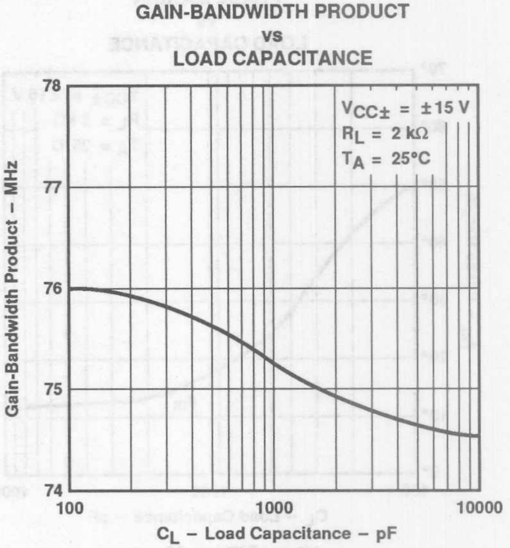

GAIN-BANDWIDTH PRODUCT
vs
LOAD CAPACITANCE

Figure 37

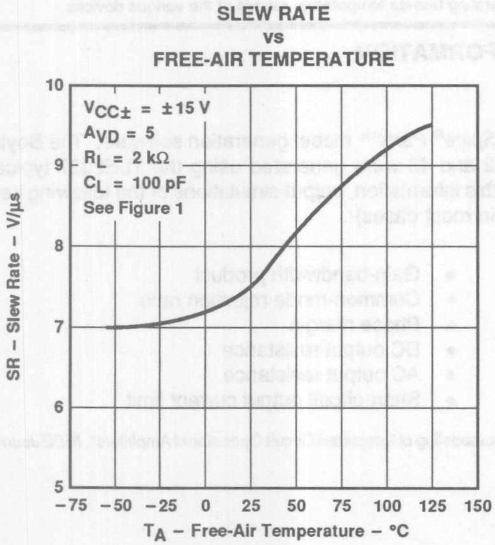

SLEW RATE
vs
FREE-AIR TEMPERATURE

Figure 38

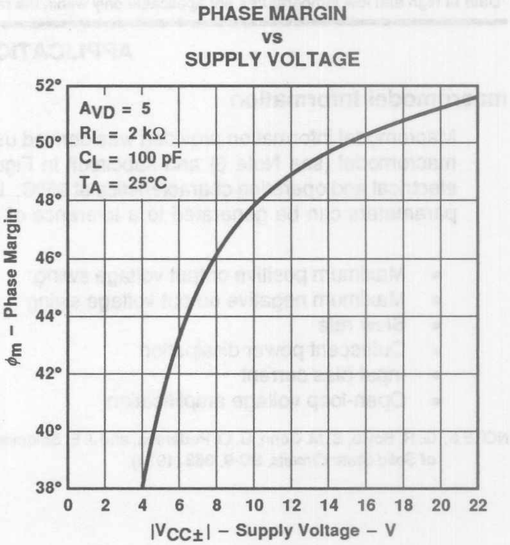

PHASE MARGIN
vs
SUPPLY VOLTAGE

Figure 39

---

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

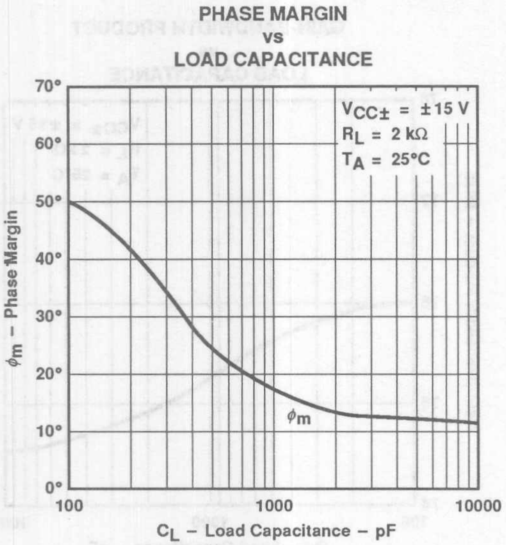


Figure 40

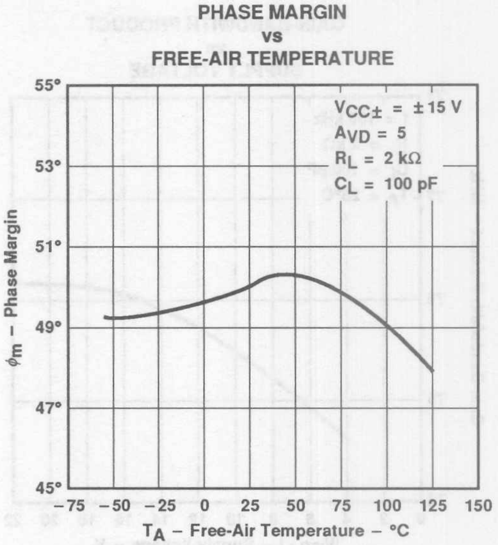


Figure 41

---

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## APPLICATION INFORMATION

### macromodel information

Macromodel information provided was derived using *PSpice®* *Parts™* model generation software. The Boyle macromodel (see Note 6) and subcircuit in Figures 42 and 43 were generated using the TLE2037 typical electrical and operating characteristics at 25°C. Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

- Maximum positive output voltage swing
- Maximum negative output voltage swing
- Slew rate
- Quiescent power dissipation
- Input bias current
- Open-loop voltage amplification
- Gain-bandwidth product
- Common-mode rejection ratio
- Phase margin
- DC output resistance
- AC output resistance
- Short-circuit output current limit

NOTE 6: G. R. Boyle, B. M. Cohn, D. O. Pederson, and J. E. Solomon, "Macromodeling of Integrated Circuit Operational Amplifiers", *IEEE Journal of Solid-State Circuits*, SC-9, 353 (1974).

*PSpice* is a registered trademark of MicroSim Corporation.
*Parts* is a trademark of MicroSim Corporation.

**Macromodels, simulation models, or other models provided by TI, directly or indirectly, are not warranted by TI as fully representing all of the specifications and operating characteristics of the semiconductor product to which the model relates.**

## APPLICATION INFORMATION

### macromodel information (continued)

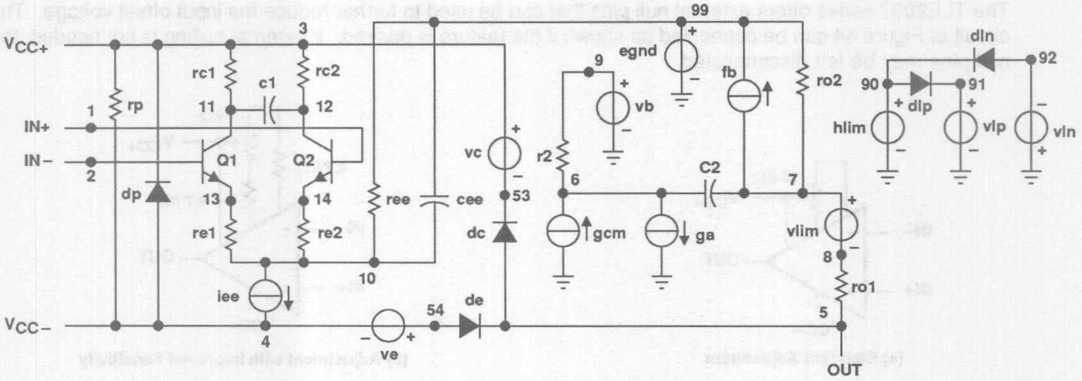


Figure 42. Boyle Macromodel

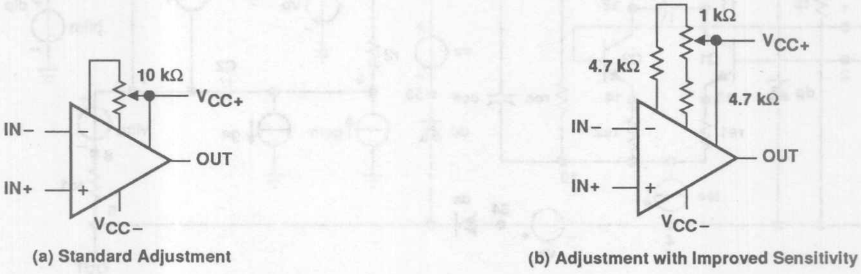
```
.subckt TLE2037  1 2 3 4 5
*
  c1   11 12 14.74E-12
  c2    6  7 7.500E-12
  dc    5 53 dx
  de   54  5 dx
  dlp  90 91 dx
  dln  92 90 dx
  dp    4  3 dx
  egnd 99  0 poly(2) (3,0) (4,0) 0 .5 .5
  fb    7 99 poly(5) vb vc ve vlp vln 0 923.4E6 -800E6 800E6 800E6 -800E6
  ga    6  0 11 12 2.121E-3
  gcm   0  6 10 99 597.7E-12
  iee  10  4 dc 56.26E-6
  hlim 90  0 vlim 1K
  q1   11  2 13 qx
  q2   12  1 14 qx
  r2    6  9 100.0E3
  rc1   3 11 471.5
  rc2   3 12 471.5
  re1  13 10 -448
  re2  14 10 -448
  ree  10 99 3.555E6
  ro1   8  5 25
  ro2   7 99 25
  rp    3  4 8.013E3
  vb    9  0 dc 0
  vc    3 53 dc 2.400
  ve   54  4 dc 2.100
  vlim  7  8 dc 0
  vlp  91  0 dc 40
  vln   0 92 dc 40
.model dx D(Is=800.0E-18)
.model qx NPN(Is=800.0E-18 Bf=7.031E3)
.ends
```

Figure 43. Macromodel Subcircuit

## APPLICATION INFORMATION

### input offset voltage nulling

The TLE2037 series offers external null pins that can be used to further reduce the input offset voltage. The circuit of Figure 44 can be connected as shown if the feature is desired. If external nulling is not needed, the null pins may be left disconnected.



**(a) Standard Adjustment**

**(b) Adjustment with Improved Sensitivity**

Figure 44. Input Offset Voltage Nulling Circuits

# TLE2061, TLE2061A, TLE2061B
# EXCALIBUR JFET-INPUT HIGH-OUTPUT-DRIVE µPOWER OPERATIONAL AMPLIFIERS

D3345, OCTOBER 1989 – REVISED JANUARY 1991

## available features

- **Excellent Output Drive Capability**
  **$V_O$ = ± 2.5 V Min at $R_L$ = 100 Ω,**
  **$V_{CC\pm}$ = ± 5 V**
  **$V_O$ = ± 12.5 V Min at $R_L$ = 600 Ω,**
  **$V_{CC\pm}$ = ± 15 V**
- **Low Supply Current . . . 280 µA Typ**
- **High Unity-Gain Bandwidth . . . 2.1 MHz Typ**
- **High Slew Rate . . . 3.4 V/µs Typ**
- **Macromodels Included**
- **Wide Operating Supply Voltage Range**
  **$V_{CC\pm}$ = ± 3.5 V to ± 20 V**
- **High Open-Loop Gain . . . 280 V/mV Typ**
- **Low Offset Voltage . . . 500 µV Max**
- **Low Offset Voltage Drift With Time**
  **0.04 µV/mo Typ**
- **Low Input Bias Current . . . 5 pA Typ**

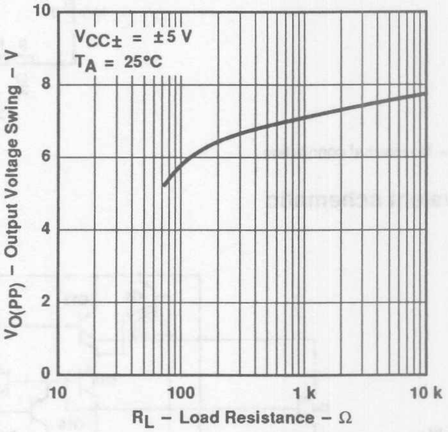
## description

The TLE2061, TLE2061A, and TLE2061B are JFET-input, low-power, precision operational amplifiers manufactured using Texas Instruments Excalibur process. These devices combine outstanding output drive capability with low-power consumption, excellent dc precision, and wide bandwidth.

In addition to maintaining the traditional JFET advantages of fast slew rates and low input bias and offset currents, the Excalibur process offers outstanding parametric stability over time and temperature. This results in a "precision" device remaining precise even with changes in temperature and over years of use.

The TLE2061, TLE2061A, and TLE2061B are ideal choices for any application requiring excellent dc precision, high output drive, wide bandwidth, and low power consumption.

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE SWING
vs
LOAD RESISTANCE



**AVAILABLE OPTIONS**

| | | PACKAGE | | | | |
|---|---|---|---|---|---|---|
| $T_A$ | $V_{IO}$ max AT 25°C | SMALL-OUTLINE (D) | CHIP CARRIER (FK) | CERAMIC DIP (JG) | METAL CAN (L) | PLASTIC DIP (P) |
| 0°C | 500 µV | — | — | — | — | TLE2061BCP |
| to | 1.5 mV | TLE2061ACD | — | — | — | TLE2061ACP |
| 70°C | 3 mV | TLE2061CD | — | — | — | TLE2061CP |
| – 40°C | 500 µV | — | — | — | — | TLE2061BIP |
| to | 1.5 mV | TLE2061AID | — | — | — | TLE2061AIP |
| 85°C | 3 mV | TLE2061ID | — | — | — | TLE2061IP |
| – 55°C | 500 µV | — | — | TLE2061BMJG | TLE2061BML | TLE2061BMP |
| to | 1.5 mV | TLE2061AMD | TLE2061AMFK | TLE2061AMJG | TLE2061AML | TLE2061AMP |
| 125°C | 3 mV | TLE2061MD | TLE2061MFK | TLE2061MJG | TLE2061ML | TLE2061MP |

D packages are available taped and reeled. Add "R" suffix to device type, (e.g., TLE2061ACDR).

PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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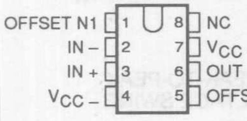
## description (continued)

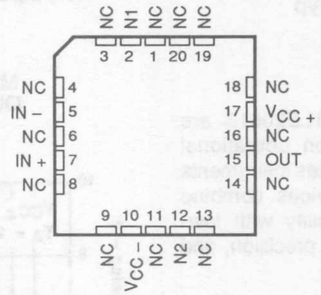
A variety of available package options includes small-outline and chip-carrier versions for high-density system applications.

The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from −40°C to 85°C. The M-suffix devices are characterized for operation over the full military temperature range of −55°C to 125°C.

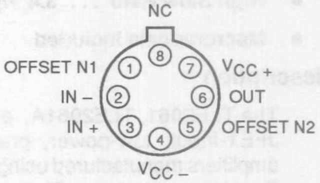
D, JG, OR P PACKAGE
(TOP VIEW)



FK PACKAGE
(TOP VIEW)



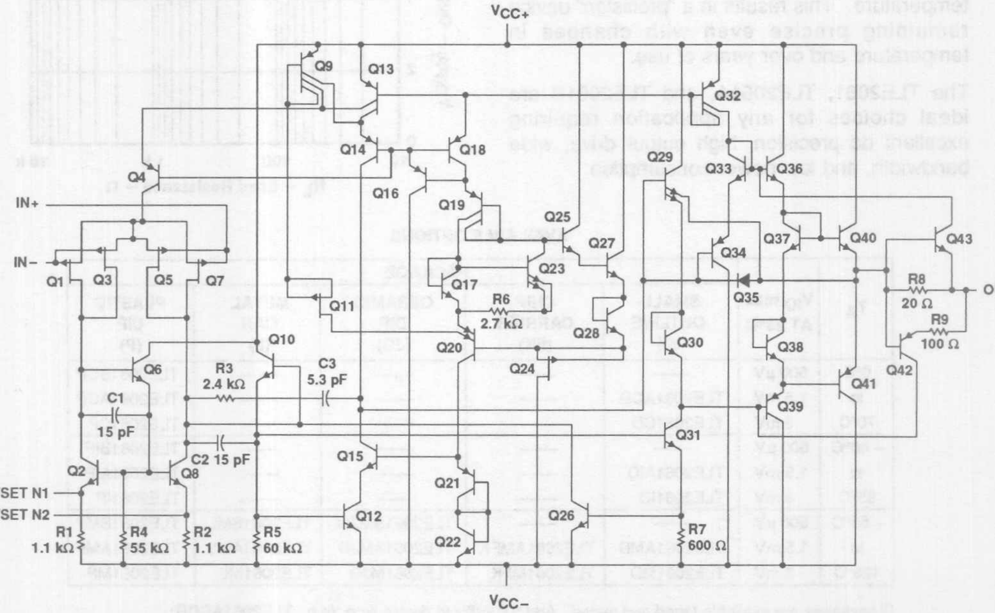
L PACKAGE
(TOP VIEW)



Pin 4 of the L package is in electrical contact with the case.

NC – No internal connection

## equivalent schematic



All component values are nominal.

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|---|
| Supply voltage, $V_{CC+}$ (see Note 1) | 22 V |
| Supply voltage, $V_{CC-}$ | −22 V |
| Differential input voltage (see Note 2) | ±44 V |
| Input voltage range, $V_I$ (any input) | $V_{CC\pm}$ |
| Input current, $I_I$ (each input) | ±1 mA |
| Output current, $I_O$ | ±80 mA |
| Total current into $V_{CC+}$ terminal | 80 mA |
| Total current out of $V_{CC-}$ terminal | 80 mA |
| Duration of short-circuit current at (or below) 25°C (see Note 3) | unlimited |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range, $T_A$: C-suffix | 0°C to 70°C |
| I-suffix | −40°C to 85°C |
| M-suffix | −55°C to 125°C |
| Storage temperature range | −65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG or L package | 300°C |

NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between $V_{CC+}$ and $V_{CC-}$.
2. Differential voltages are at the noninverting input with respect to the inverting input.
3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

### DISSIPATION RATING TABLE

| PACKAGE | $T_A \le 25°C$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25°C$ | $T_A = 70°C$ POWER RATING | $T_A = 85°C$ POWER RATING | $T_A = 125°C$ POWER RATING |
|---|---|---|---|---|---|
| D | 725 mW | 5.8 mW/°C | 464 mW | 377 mW | 145 mW |
| FK | 1375 mW | 11.0 mW/°C | 880 mW | 715 mW | 275 mW |
| JG | 1050 mW | 8.4 mW/°C | 672 mW | 546 mW | 210 mW |
| L | 650 mW | 5.2 mW/°C | 416 mW | 338 mW | 130 mW |
| P | 1000 mW | 8.0 mW/°C | 640 mW | 520 mW | 200 mW |

## recommended operating conditions

| | | C-SUFFIX | | I-SUFFIX | | M-SUFFIX | | UNIT |
|---|---|---|---|---|---|---|---|---|
| | | MIN | MAX | MIN | MAX | MIN | MAX | |
| Supply voltage, $V_{CC\pm}$ | | ± 3.5 | ± 20 | ± 3.5 | ± 20 | ± 3.5 | ± 20 | V |
| Common-mode input voltage, $V_{IC}$ | $V_{CC\pm} = \pm 5$ V | − 1.6 | 4 | − 1.6 | 4 | − 1.6 | 4 | V |
| | $V_{CC\pm} = \pm 15$ V | − 11 | 13 | − 11 | 13 | − 11 | 13 | |
| | $V_{CC\pm} = \pm 20$ V | − 15 | 16.5 | − 15 | 16.5 | − 15 | 16.5 | |
| Operating free-air temperature, $T_A$ | | 0 | 70 | − 40 | 85 | − 55 | 125 | °C |

## electrical characteristics at specified free-air temperature, $V_{CC\pm}$ = ±5 V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2061C | $V_{IC}$ = 0, $R_S$ = 50 Ω | 25°C | | 0.8 | 3.1 | mV |
| | | | | Full range | | | 4 | |
| | | TLE2061AC | | 25°C | | 0.6 | 2.6 | |
| | | | | Full range | | | 3.5 | |
| | | TLE2061BC | | 25°C | | 0.5 | 1.9 | |
| | | | | Full range | | | 2.4 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | μV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | μV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 1 | | pA |
| | | | | Full range | | | 0.8 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 3 | | pA |
| | | | | Full range | | | 2 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | − 1.6<br>to<br>4 | − 2<br>to<br>6 | | V |
| | | | | Full range | − 1.6<br>to<br>4 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L$ = 10 kΩ | 25°C | 3.5 | 3.7 | | V |
| | | | | Full range | 3.3 | | | |
| | | | $R_L$ = 100 Ω | 25°C | 2.5 | 3.1 | | |
| | | | | Full range | 2 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L$ = 10 kΩ | 25°C | − 3.7 | − 3.9 | | V |
| | | | | Full range | − 3.3 | | | |
| | | | $R_L$ = 100 Ω | 25°C | − 2.5 | − 2.7 | | |
| | | | | Full range | − 2 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O$ = ± 2.8 V, $R_L$ = 10 kΩ | 25°C | 15 | 80 | | V/mV |
| | | | | Full range | 2 | | | |
| | | | $V_O$ = 0 to 2 V, $R_L$ = 100 Ω | 25°C | 0.75 | 45 | | |
| | | | | Full range | 0.5 | | | |
| | | | $V_O$ = 0 to − 2 V, $R_L$ = 100 Ω | 25°C | 0.5 | 3 | | |
| | | | | Full range | 0.25 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O$ = 0 | 25°C | | 280 | | Ω |
| CMRR | Common-mode rejection ratio | | $R_S$ = 50 Ω, $V_{IC}$ = $V_{ICR}$ min | 25°C | 65 | 82 | | dB |
| | | | | Full range | 65 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm}$ = ±5 V to ± 20 V, $R_S$ = 50 Ω | 25°C | 75 | 93 | | dB |
| | | | | Full range | 75 | | | |
| $I_{CC}$ | Supply current | | $V_O$ = 0, No load | 25°C | | 280 | 325 | μA |
| | | | | Full range | | | 350 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | | Full range | | 29 | | μA |

†Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A$ = 150°C extrapolated to $T_A$ = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L = 10\ k\Omega$, | $C_L = 100$ pF | 25°C | 2.2 | 3.4 | | V/μs |
| | | | | Full range | 2.1 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S = 100\ \Omega$ | 25°C | | 59 | 100 | nV/√Hz |
| | | f = 1 kHz, | $R_S = 100\ \Omega$ | 25°C | | 43 | 60 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | 25°C | | 1.1 | | μV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | 25°C | | 1 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD} = 2$,<br>$V_{O(PP)} = 2$ V, | f = 10 kHz,<br>$R_L = 10\ k\Omega$ | 25°C | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L = 10\ k\Omega$, | $C_L = 100$ pF | 25°C | | 1.8 | | MHz |
| | | $R_L = 100\ \Omega$, | $C_L = 100$ pF | 25°C | | 1.3 | | |
| | Settling time | 0.1% | | 25°C | | 5 | | μs |
| | | 0.01% | | 25°C | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD} = 1$, | $R_L = 10\ k\Omega$ | 25°C | | 140 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L = 10\ k\Omega$, | $C_L = 100$ pF | 25°C | | 58° | | |
| | | $R_L = 100\ \Omega$, | $C_L = 100$ pF | 25°C | | 75° | | |

†Full range is 0°C to 70°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2061C | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 0.6 | 3 | mV |
| | | | | Full range | | | 3.9 | |
| | | TLE2061AC | | 25°C | | 0.5 | 1.5 | |
| | | | | Full range | | | 2.5 | |
| | | TLE2061BC | | 25°C | | 0.3 | 0.5 | |
| | | | | Full range | | | 1 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | µV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 2 | | pA |
| | | | | Full range | | | 1 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 4 | | pA |
| | | | | Full range | | | 3 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | − 11<br>to<br>13 | − 12<br>to<br>16 | | V |
| | | | | Full range | − 11<br>to<br>13 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 13.2 | 13.7 | | V |
| | | | | Full range | 13 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | 12.5 | 13.2 | | |
| | | | | Full range | 12 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | − 13.2 | − 13.7 | | V |
| | | | | Full range | − 13 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | − 12.5 | − 13 | | |
| | | | | Full range | − 12 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 10$ V, $R_L = 10\ k\Omega$ | 25°C | 30 | 230 | | V/mV |
| | | | | Full range | 20 | | | |
| | | | $V_O = 0$ to 8 V, $R_L = 600\ \Omega$ | 25°C | 25 | 100 | | |
| | | | | Full range | 10 | | | |
| | | | $V_O = 0$ to $-8$ V, $R_L = 600\ \Omega$ | 25°C | 3 | 25 | | |
| | | | | Full range | 1 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | 25°C | | 280 | | Ω |
| CMRR | Common-mode rejection ratio | | $R_S = 50\ \Omega$,<br>$V_{IC} = V_{ICR}$ min | 25°C | 72 | 90 | | dB |
| | | | | Full range | 70 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to $\pm 15$ V,<br>$R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | | | Full range | 75 | | | |
| $I_{CC}$ | Supply current | | $V_O = 0$, No load | 25°C | | 290 | 350 | µA |
| | | | | Full range | | | 375 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | | Full range | | 34 | | µA |

†Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | 2.6 | 3.4 | | V/µs |
| | | | | Full range | 2.5 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S$ = 100 Ω | 25°C | | 70 | 100 | nV/√Hz |
| | | f = 1 kHz, | $R_S$ = 100 Ω | 25°C | | 40 | 60 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | 25°C | | 1.1 | | µV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | 25°C | | 1.1 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD}$ = 2,<br>$V_{O(PP)}$ = 2 V, | f = 10 kHz,<br>$R_L$ = 10 kΩ | 25°C | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 2 | | MHz |
| | | $R_L$ = 600 Ω, | $C_L$ = 100 pF | 25°C | | 1.5 | | |
| | Settling time | 0.1% | | 25°C | | 5 | | µs |
| | | 0.01% | | 25°C | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD}$ = 1, | $R_L$ = 10 kΩ | 25°C | | 40 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 60° | | |
| | | $R_L$ = 600 Ω, | $C_L$ = 100 pF | 25°C | | 70° | | |

† Full range is 0°C to 70°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 20$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2061C | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 0.6 | 3 | mV |
| | | | | Full range | | | 3.9 | |
| | | TLE2061AC | | 25°C | | 0.6 | 1.6 | |
| | | | | Full range | | | 2.5 | |
| | | TLE2061BC | | 25°C | | 0.3 | 0.5 | |
| | | | | Full range | | | 1 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | µV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 3 | | pA |
| | | | | Full range | | | 1 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 5 | | pA |
| | | | | Full range | | | 3 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | − 15<br>to<br>16.5 | − 17<br>to<br>21 | | V |
| | | | | Full range | − 15<br>to<br>16.5 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 18.2 | 18.7 | | V |
| | | | | Full range | 18 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | 15 | 18.1 | | |
| | | | | Full range | 12 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | − 18.2 | − 18.7 | | V |
| | | | | Full range | − 18 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | − 15 | − 18 | | |
| | | | | Full range | − 12 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 15$ V, $R_L = 10\ k\Omega$ | 25°C | 30 | 280 | | V/mV |
| | | | | Full range | 20 | | | |
| | | | $V_O = 0$ to 10 V, $R_L = 600\ \Omega$ | 25°C | 25 | 80 | | |
| | | | | Full range | 10 | | | |
| | | | $V_O = 0$ to − 10 V, $R_L = 600\ \Omega$ | 25°C | 3 | 20 | | |
| | | | | Full range | 1 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | 25°C | | 280 | | Ω |
| CMRR | Common-mode rejection ratio | | $R_S = 50\ \Omega$,<br>$V_{IC} = V_{ICR}$ min | 25°C | 75 | 91 | | dB |
| | | | | Full range | 70 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to $\pm 20$ V,<br>$R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | | | Full range | 70 | | | |
| $I_{CC}$ | Supply current | | $V_O = 0$, No load | 25°C | | 300 | 375 | µA |
| | | | | Full range | | | 400 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | | Full range | | 18 | | µA |

†Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 20$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$[†] | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L = 10\ k\Omega$, | $C_L = 100$ pF | 25°C | 2.8 | 3.4 | | V/μs |
| | | | | Full range | 2.5 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S = 100\ \Omega$ | 25°C | | 75 | 100 | nV/√Hz |
| | | f = 1 kHz, | $R_S = 100\ \Omega$ | 25°C | | 40 | 60 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | 25°C | | 1.1 | | μV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | 25°C | | 1.3 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD} = 2$,<br>$V_{O(PP)} = 2$ V, | f = 10 kHz,<br>$R_L = 10\ k\Omega$ | 25°C | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L = 10\ k\Omega$, | $C_L = 100$ pF | 25°C | | 2.1 | | MHz |
| | | $R_L = 600\ \Omega$, | $C_L = 100$ pF | 25°C | | 1.6 | | |
| | Settling time | 0.1% | | 25°C | | 5 | | μs |
| | | 0.01% | | 25°C | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD} = 1$, | $R_L = 10\ k\Omega$ | 25°C | | 28 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L = 10\ k\Omega$, | $C_L = 100$ pF | 25°C | | 60° | | |
| | | $R_L = 600\ \Omega$, | $C_L = 100$ pF | 25°C | | 70° | | |

[†] Full range is 0°C to 70°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 5$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2061I | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 0.8 | 3.1 | mV |
| | | | | Full range | | | 4.4 | |
| | | TLE2061AI | | 25°C | | 0.6 | 2.6 | |
| | | | | Full range | | | 3.9 | |
| | | TLE2061BI | | 25°C | | 0.5 | 1.9 | |
| | | | | Full range | | | 2.7 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | µV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 1 | | pA |
| | | | | Full range | | | 2 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 3 | | pA |
| | | | | Full range | | | 4 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | − 1.6<br>to<br>4 | − 2<br>to<br>6 | | V |
| | | | | Full range | − 1.6<br>to<br>4 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 3.5 | 3.7 | | V |
| | | | | Full range | 3.1 | | | |
| | | | $R_L = 100\ \Omega$ | 25°C | 2.5 | 3.1 | | |
| | | | | Full range | 2 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | − 3.7 | − 3.9 | | V |
| | | | | Full range | − 3.1 | | | |
| | | | $R_L = 100\ \Omega$ | 25°C | − 2.5 | − 2.7 | | |
| | | | | Full range | − 2 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 2.8$ V, $R_L = 10\ k\Omega$ | 25°C | 15 | 80 | | V/mV |
| | | | | Full range | 2 | | | |
| | | | $V_O = 0$ to 2 V, $R_L = 100\ \Omega$ | 25°C | 0.75 | 45 | | |
| | | | | Full range | 0.5 | | | |
| | | | $V_O = 0$ to − 2 V, $R_L = 100\ \Omega$ | 25°C | 0.5 | 3 | | |
| | | | | Full range | 0.25 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | 25°C | | 280 | | Ω |
| CMRR | Common-mode rejection ratio | | $R_S = 50\ \Omega$,<br>$V_{IC} = V_{ICR}$ min | 25°C | 65 | 82 | | dB |
| | | | | Full range | 65 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to $\pm 20$ V,<br>$R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | | | Full range | 65 | | | |
| $I_{CC}$ | Supply current | | $V_O = 0$, No load | 25°C | | 280 | 325 | µA |
| | | | | Full range | | | 350 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | | Full range | | 29 | | µA |

†Full range is − 40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$[†] | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | 2.2 | 3.4 | | V/µs |
| | | | | Full range | 1.7 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S$ = 100 Ω | 25°C | | 59 | 100 | nV/√Hz |
| | | f = 1 kHz, | $R_S$ = 100 Ω | 25°C | | 43 | 60 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | 25°C | | 1.1 | | µV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | 25°C | | 1 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD}$ = 2,<br>$V_{O(PP)}$ = 2 V, | f = 10 kHz,<br>$R_L$ = 10 kΩ | 25°C | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 1.8 | | MHz |
| | | $R_L$ = 100 Ω, | $C_L$ = 100 pF | 25°C | | 1.3 | | |
| | Settling time | 0.1% | | 25°C | | 5 | | µs |
| | | 0.01% | | 25°C | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD}$ = 1, | $R_L$ = 10 kΩ | 25°C | | 140 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 58° | | |
| | | $R_L$ = 100 Ω, | $C_L$ = 100 pF | 25°C | | 75° | | |

[†] Full range is – 40°C to 85°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2061I | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 0.6 | 3 | mV |
| | | | | Full range | | | 4.3 | |
| | | TLE2061AI | | 25°C | | 0.5 | 1.5 | |
| | | | | Full range | | | 2.9 | |
| | | TLE2061BI | | 25°C | | 0.3 | 0.5 | |
| | | | | Full range | | | 1.3 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | µV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 2 | | pA |
| | | | | Full range | | | 3 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 4 | | pA |
| | | | | Full range | | | 5 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | − 11<br>to<br>13 | − 12<br>to<br>16 | | V |
| | | | | Full range | − 11<br>to<br>13 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $R_L = 10\ k\Omega$ | | 25°C | 13.2 | 13.7 | | V |
| | | | | Full range | 13 | | | |
| | | $R_L = 600\ \Omega$ | | 25°C | 12.5 | 13.2 | | |
| | | | | Full range | 12 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | $R_L = 10\ k\Omega$ | | 25°C | − 13.2 | − 13.7 | | V |
| | | | | Full range | − 13 | | | |
| | | $R_L = 600\ \Omega$ | | 25°C | − 12.5 | − 13 | | |
| | | | | Full range | − 12 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = \pm 10$ V, | $R_L = 10\ k\Omega$ | 25°C | 30 | 230 | | V/mV |
| | | | | Full range | 20 | | | |
| | | $V_O = 0$ to 8 V, | $R_L = 600\ \Omega$ | 25°C | 25 | 100 | | |
| | | | | Full range | 10 | | | |
| | | $V_O = 0$ to − 8 V, | $R_L = 600\ \Omega$ | 25°C | 3 | 25 | | |
| | | | | Full range | 1 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | $I_O = 0$ | | 25°C | | 280 | | Ω |
| CMRR | Common-mode rejection ratio | $R_S = 50\ \Omega$,<br>$V_{IC} = V_{ICR}$ min | | 25°C | 72 | 90 | | dB |
| | | | | Full range | 65 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 5$ V to ± 15 V,<br>$R_S = 50\ \Omega$ | | 25°C | 75 | 93 | | dB |
| | | | | Full range | 65 | | | |
| $I_{CC}$ | Supply current | $V_O = 0$, | No load | 25°C | | 290 | 350 | µA |
| | | | | Full range | | | 375 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | | Full range | | 34 | | µA |

†Full range is − 40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm}$ = ± 15 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | 2.6 | 3.4 | | V/µs |
| | | | | Full range | 2.1 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S$ = 100 Ω | 25°C | | 70 | 100 | nV/√Hz |
| | | f = 1 kHz, | $R_S$ = 100 Ω | 25°C | | 40 | 60 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | 25°C | | 1.1 | | µV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | 25°C | | 1.1 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD}$ = 2,<br>$V_{O(PP)}$ = 2 V, | f = 10 kHz,<br>$R_L$ = 10 kΩ | 25°C | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 2 | | MHz |
| | | $R_L$ = 600 Ω, | $C_L$ = 100 pF | 25°C | | 1.5 | | |
| | Settling time | 0.1% | | 25°C | | 5 | | µs |
| | | 0.01% | | 25°C | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD}$ = 1, | $R_L$ = 10 kΩ | 25°C | | 40 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 60° | | |
| | | $R_L$ = 600 Ω, | $C_L$ = 100 pF | 25°C | | 70° | | |

†Full range is – 40°C to 85°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 20$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2061I | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 0.6 | 3 | mV |
| | | | | Full range | | | 4.3 | |
| | | TLE2061AI | | 25°C | | 0.6 | 1.6 | |
| | | | | Full range | | | 2.9 | |
| | | TLE2061BI | | 25°C | | 0.3 | 0.5 | |
| | | | | Full range | | | 1.3 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | μV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | μV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 3 | | pA |
| | | | | Full range | | | 3 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 5 | | pA |
| | | | | Full range | | | 5 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | − 15<br>to<br>16.5 | − 17<br>to<br>21 | | V |
| | | | | Full range | − 15<br>to<br>16.5 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 18.2 | 18.7 | | V |
| | | | | Full range | 18 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | 15 | 18.1 | | |
| | | | | Full range | 12 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | − 18.2 | − 18.7 | | V |
| | | | | Full range | − 18 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | − 15 | − 18 | | |
| | | | | Full range | − 12 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 15$ V, $R_L = 10\ k\Omega$ | 25°C | 30 | 280 | | V/mV |
| | | | | Full range | 20 | | | |
| | | | $V_O = 0$ to 10 V, $R_L = 600\ \Omega$ | 25°C | 25 | 80 | | |
| | | | | Full range | 10 | | | |
| | | | $V_O = 0$ to − 10 V, $R_L = 600\ \Omega$ | 25°C | 3 | 20 | | |
| | | | | Full range | 1 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | 25°C | | 280 | | Ω |
| CMRR | Common-mode rejection ratio | | $R_S = 50\ \Omega$,<br>$V_{IC} = V_{ICR}$ min | 25°C | 75 | 91 | | dB |
| | | | | Full range | 65 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to $\pm 20$ V,<br>$R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | | | Full range | 65 | | | |
| $I_{CC}$ | Supply current | | $V_O = 0$, No load | 25°C | | 300 | 375 | μA |
| | | | | Full range | | | 400 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | | Full range | | 36 | | μA |

†Full range is – 40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 20$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | 2.8 | 3.4 | | V/μs |
| | | | | Full range | 2.1 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S$ = 100 Ω | 25°C | | 75 | 100 | nV/√Hz |
| | | f = 1 kHz, | $R_S$ = 100 Ω | 25°C | | 40 | 60 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | 25°C | | 1.1 | | μV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | 25°C | | 1.3 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD}$ = 2,<br>$V_{O(PP)}$ = 2 V, | f = 10 kHz,<br>$R_L$ = 10 kΩ | 25°C | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 2.1 | | MHz |
| | | $R_L$ = 600 Ω, | $C_L$ = 100 pF | 25°C | | 1.6 | | |
| | Settling time | 0.1% | | 25°C | | 5 | | μs |
| | | 0.01% | | 25°C | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD}$ = 1, | $R_L$ = 10 kΩ | 25°C | | 28 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 60° | | |
| | | $R_L$ = 600 Ω, | $C_L$ = 100 pF | 25°C | | 70° | | |

† Full range is – 40°C to 85°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 5$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2061M | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 0.8 | 3.1 | mV |
| | | | | Full range | | | 6 | |
| | | TLE2061AM | | 25°C | | 0.6 | 2.6 | |
| | | | | Full range | | | 4.6 | |
| | | TLE2061BM | | 25°C | | 0.5 | 1.9 | |
| | | | | Full range | | | 3.1 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | µV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 1 | | pA |
| | | | | Full range | | | 15 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 3 | | pA |
| | | | | Full range | | | 30 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | −1.6<br>to<br>4 | −2<br>to<br>6 | | V |
| | | | | Full range | −1.6<br>to<br>4 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 3.5 | 3.7 | | V |
| | | | | Full range | 3 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | 2.5 | 3.6 | | |
| | | | | Full range | 2 | | | |
| | | | $R_L = 100\ \Omega$ | 25°C | 2.5 | 3.1 | | |
| | | | | Full range | 2 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | −3.5 | −3.9 | | V |
| | | | | Full range | −3 | | | |
| | | FK, JG, and L packages | $R_L = 600\ \Omega$ | 25°C | −2.5 | −3.5 | | |
| | | | | Full range | −2 | | | |
| | | D and P packages | $R_L = 100\ \Omega$ | 25°C | −2.5 | −2.7 | | |
| | | | | Full range | −2 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 2.8$ V, $R_L = 10\ k\Omega$ | 25°C | 15 | 80 | | V/mV |
| | | | | Full range | 2 | | | |
| | | FK, JG, and L packages | $V_O = 0$ to 2.5 V, $R_L = 600\ \Omega$ | 25°C | 1 | 65 | | |
| | | | | Full range | 0.5 | | | |
| | | | $V_O = 0$ to −2.5 V, $R_L = 600\ \Omega$ | 25°C | 1 | 16 | | |
| | | | | Full range | 0.5 | | | |
| | | D and P packages | $V_O = 0$ to 2 V, $R_L = 100\ \Omega$ | 25°C | 0.75 | 45 | | |
| | | | | Full range | 0.5 | | | |
| | | | $V_O = 0$ to −2 V, $R_L = 100\ \Omega$ | 25°C | 0.5 | 3 | | |
| | | | | Full range | 0.25 | | | |

†Full range is −55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm5$ V (unless otherwise noted) (continued)

| PARAMETER | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $r_i$ | Input resistance | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | $I_O = 0$ | 25°C | | 280 | | Ω |
| CMRR | Common-mode rejection ratio | $R_S = 50\ \Omega$,<br>$V_{IC} = V_{ICR}$ min | 25°C | 65 | 82 | | dB |
| | | | Full range | 60 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$) | $V_{CC\pm} = \pm5$ V to $\pm20$ V,<br>$R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | | Full range | 65 | | | |
| $I_{CC}$ | Supply current | $V_O = 0$, No load | 25°C | | 280 | 325 | μA |
| | | | Full range | | | 350 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | Full range | | 39 | | μA |

†Full range is – 55°C to 125°C.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L = 10\ \text{k}\Omega$, | $C_L = 100$ pF | 25°C | | 3.4 | | V/μs |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S = 100\ \Omega$ | 25°C | | 59 | | nV/√Hz |
| | | f = 1 kHz, | $R_S = 100\ \Omega$ | 25°C | | 43 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | 25°C | | 1.1 | | μV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | 25°C | | 1 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD} = 2$,<br>$V_{O(PP)} = 2$ V, | f = 10 kHz,<br>$R_L = 10\ \text{k}\Omega$ | 25°C | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L = 10\ \text{k}\Omega$, | $C_L = 100$ pF | 25°C | | 1.8 | | MHz |
| | | $R_L = 600\ \Omega$, | $C_L = 100$ pF | 25°C | | 1.3 | | |
| | Settling time | 0.1% | | 25°C | | 5 | | μs |
| | | 0.01% | | 25°C | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD} = 1$, | $R_L = 10\ \text{k}\Omega$ | 25°C | | 140 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L = 10\ \text{k}\Omega$, | $C_L = 100$ pF | 25°C | | 58° | | |
| | | $R_L = 600\ \Omega$, | $C_L = 100$ pF | 25°C | | 75° | | |

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2061M | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 0.6 | 3 | mV |
| | | | | Full range | | | 6 | |
| | | TLE2061AM | | 25°C | | 0.5 | 1.5 | |
| | | | | Full range | | | 3.6 | |
| | | TLE2061BM | | 25°C | | 0.3 | 0.5 | |
| | | | | Full range | | | 1.7 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | μV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | μV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 2 | | pA |
| | | | | Full range | | | 20 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 4 | | pA |
| | | | | Full range | | | 40 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | −11<br>to<br>13 | −12<br>to<br>16 | | V |
| | | | | Full range | −11<br>to<br>13 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 13 | 13.7 | | V |
| | | | | Full range | 12.5 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | 12.5 | 13.2 | | |
| | | | | Full range | 12 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | −13 | −13.7 | | V |
| | | | | Full range | −12.5 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | −12.5 | −13 | | |
| | | | | Full range | −12 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 10$ V, $R_L = 10\ k\Omega$ | 25°C | 30 | 230 | | V/mV |
| | | | | Full range | 20 | | | |
| | | | $V_O = 0$ to 8 V, $R_L = 600\ \Omega$ | 25°C | 25 | 100 | | |
| | | | | Full range | 7 | | | |
| | | | $V_O = 0$ to $-8$ V, $R_L = 600\ \Omega$ | 25°C | 3 | 25 | | |
| | | | | Full range | 1 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | 25°C | | 280 | | Ω |
| CMRR | Common-mode rejection ratio | | $R_S = 50\ \Omega$,<br>$V_{IC} = V_{ICR}$ min | 25°C | 72 | 90 | | dB |
| | | | | Full range | 65 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to $\pm 15$ V,<br>$R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | | | Full range | 65 | | | |
| $I_{CC}$ | Supply current | | $V_O = 0$, No load | 25°C | | 290 | 350 | μA |
| | | | | Full range | | | 375 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | | Full range | | 46 | | μA |

†Full range is − 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm}$ = ±15 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | 2 | 3.4 | | V/μs |
| | | | | Full range | 1.8 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S$ = 100 Ω | 25°C | | 70 | | nV/√Hz |
| | | f = 1 kHz, | $R_S$ = 100 Ω | 25°C | | 40 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | 25°C | | 1.1 | | μV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | 25°C | | 1.1 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD}$ = 2,<br>$V_{O(PP)}$ = 2 V, | f = 10 kHz,<br>$R_L$ = 10 kΩ | 25°C | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 2 | | MHz |
| | | $R_L$ = 600 Ω, | $C_L$ = 100 pF | 25°C | | 1.5 | | |
| | Settling time | 0.1% | | 25°C | | 5 | | μs |
| | | 0.01% | | 25°C | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD}$ = 1, | $R_L$ = 10 kΩ | 25°C | | 40 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 60° | | |
| | | $R_L$ = 600 Ω, | $C_L$ = 100 pF | 25°C | | 70° | | |

†Full range is – 55°C to 125°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 20$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2061M | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 0.6 | 3 | mV |
| | | | | Full range | | | 6 | |
| | | TLE2061AM | | 25°C | | 0.6 | 1.6 | |
| | | | | Full range | | | 3.6 | |
| | | TLE2061BM | | 25°C | | 0.3 | 0.5 | |
| | | | | Full range | | | 1.7 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | µV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 3 | | pA |
| | | | | Full range | | | 20 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 5 | | pA |
| | | | | Full range | | | 40 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | − 15<br>to<br>16.5 | − 17<br>to<br>21 | | V |
| | | | | Full range | − 15<br>to<br>16.5 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 18 | 18.7 | | V |
| | | | | Full range | 17.5 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | 15 | 18.1 | | |
| | | | | Full range | 12 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | − 18 | − 18.7 | | V |
| | | | | Full range | − 17.5 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | − 15 | − 18 | | |
| | | | | Full range | − 12 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 15$ V, $R_L = 10\ k\Omega$ | 25°C | 30 | 280 | | V/mV |
| | | | | Full range | 20 | | | |
| | | | $V_O = 0$ to 10 V, $R_L = 600\ \Omega$ | 25°C | 25 | 80 | | |
| | | | | Full range | 10 | | | |
| | | | $V_O = 0$ to − 10 V, $R_L = 600\ \Omega$ | 25°C | 3 | 20 | | |
| | | | | Full range | 1 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | 25°C | | 280 | | Ω |
| CMRR | Common-mode rejection ratio | | $R_S = 50\ \Omega$,<br>$V_{IC} = V_{ICR}$ min | 25°C | 75 | 91 | | dB |
| | | | | Full range | 65 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to ± 20 V,<br>$R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | | | Full range | 65 | | | |
| $I_{CC}$ | Supply current | | $V_O = 0$, No load | 25°C | | 300 | 375 | µA |
| | | | | Full range | | | 400 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | | Full range | | 50 | | µA |

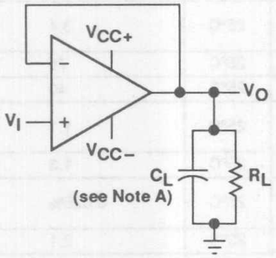
†Full range is − 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 20$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 3.4 | | V/μs |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S$ = 100 Ω | 25°C | | 75 | | nV/√Hz |
| | | f = 1 kHz, | $R_S$ = 100 Ω | 25°C | | 40 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | 25°C | | 1.1 | | μV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | 25°C | | 1.3 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD}$ = 2,<br>$V_{O(PP)}$ = 2 V, | f = 10 kHz,<br>$R_L$ = 10 kΩ | 25°C | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 2.1 | | MHz |
| | | $R_L$ = 600 Ω, | $C_L$ = 100 pF | 25°C | | 1.6 | | |
| | Settling time | 0.1% | | 25°C | | 5 | | μs |
| | | 0.01% | | 25°C | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD}$ = 1, | $R_L$ = 10 kΩ | 25°C | | 28 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 60° | | |
| | | $R_L$ = 600 Ω, | $C_L$ = 100 pF | 25°C | | 70° | | |

## PARAMETER MEASUREMENT INFORMATION



NOTE A: $C_L$ includes fixture capacitance.

Figure 1. Slew Rate Test Circuit

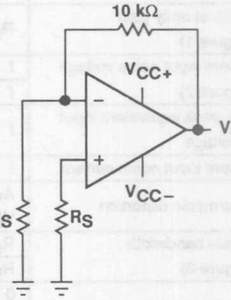
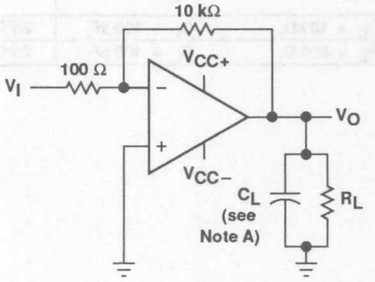


Figure 2. Noise Voltage Test Circuit



NOTE A: $C_L$ includes fixture capacitance.

Figure 3. Unity-Gain Bandwidth and Phase Margin Test Circuit

### typical values

Typical values as presented in this data sheet represent the median (50% point) of device parametric performance.

### input bias and offset current

At the picoamp bias current level typical of the TLE2061, TLE2061A, and TLE2061B, accurate measurement of the bias current becomes difficult. Not only does this measurement require a picoammeter, but test socket leakages can easily exceed the actual device bias currents. To accurately measure these small currents, Texas Instruments uses a two-step process. The socket leakage is measured using picoammeters with bias voltages applied but with no device in the socket. The device is then inserted into the socket and a second test that measures both the socket leakage and the device input bias current is performed. The two measurements are then subtracted algebraically to determine the bias current of the device.

## TYPICAL CHARACTERISTICS

### table of graphs

| | | | FIGURE |
|---|---|---|---|
| $V_{IO}$ | Input offset voltage | Distribution | 4 |
| $I_{IB}$ | Input bias current | vs Common-mode voltage | 5 |
| | | vs Temperature | 6 |
| $I_{IO}$ | Input offset current | vs Temperature | 6 |
| $V_{ICR}$ | Common-mode input voltage range limits | vs Temperature | 7 |
| $V_{OM}$ | Maximum peak output voltage swing | vs Output current | 8, 9 |
| | | vs Supply voltage | 10, 11, 12 |
| $V_{O(PP)}$ | Maximum peak-to-peak output voltage | vs Frequency | 13, 14, 15 |
| $A_{VD}$ | Differential voltage amplification | vs Frequency | 16 |
| | | vs Temperature | 17 |
| $I_{OS}$ | Short-circuit output current | vs Time | 18 |
| | | vs Temperature | 19 |
| $z_o$ | Output impedance | vs Frequency | 20 |
| CMRR | Common-mode rejection ratio | vs Frequency | 21 |
| $I_{CC}$ | Supply current | vs Supply voltage | 22 |
| | | vs Temperature | 23 |
| | Pulse response | Small-signal | 24, 25 |
| | | Large-signal | 26, 27 |
| | Noise voltage (referred to input) | 0.1 to 10 Hz | 28 |
| $V_n$ | Equivalent input noise voltage | vs Frequency | 29 |
| THD | Total harmonic distortion | vs Frequency | 30, 31 |
| $B_1$ | Unity-gain bandwidth | vs Supply voltage | 32 |
| | | vs Temperature | 33 |
| $\phi_m$ | Phase margin | vs Supply voltage | 34 |
| | | vs Load capacitance | 35 |
| | | vs Temperature | 36 |
| | Phase shift | vs Frequency | 16 |

## TYPICAL CHARACTERISTICS†

TLE2061
DISTRIBUTION OF
INPUT OFFSET VOLTAGE

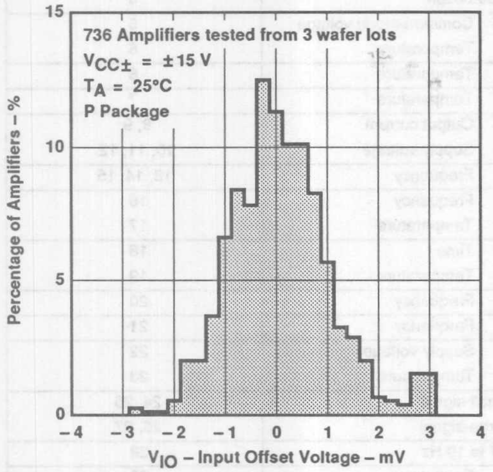


Figure 4

INPUT BIAS CURRENT
vs
COMMON-MODE INPUT VOLTAGE

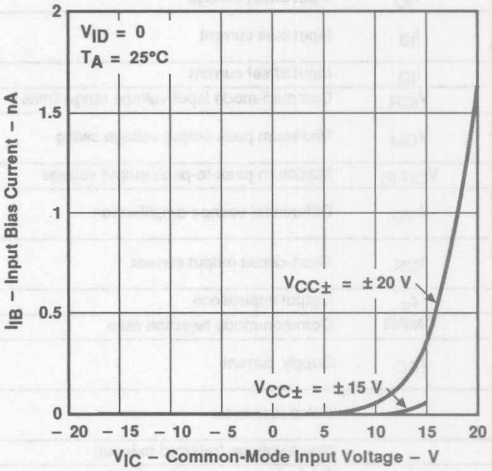


Figure 5

INPUT BIAS CURRENT
and INPUT OFFSET CURRENT
vs
FREE-AIR TEMPERATURE

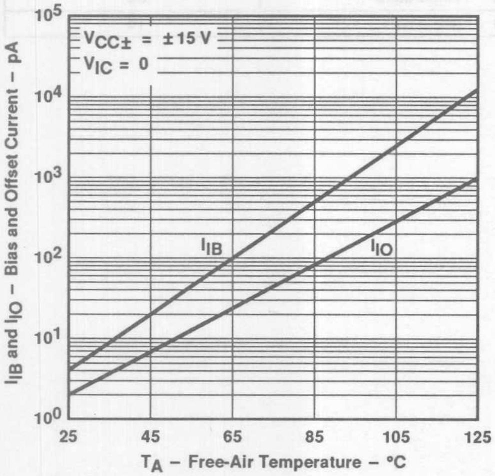


Figure 6

COMMON-MODE
INPUT VOLTAGE RANGE LIMITS
vs
FREE-AIR TEMPERATURE

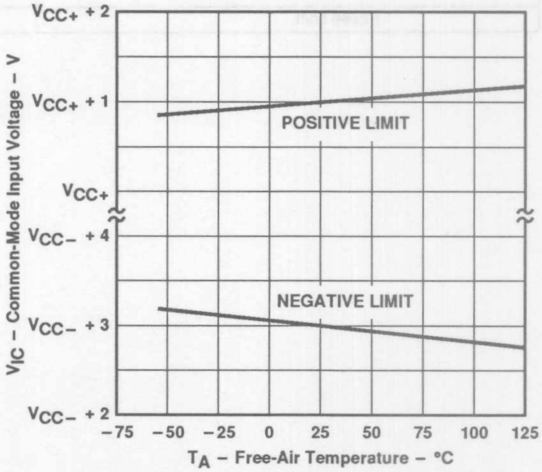


Figure 7

---

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS

MAXIMUM POSITIVE PEAK
OUTPUT VOLTAGE
vs
OUTPUT CURRENT

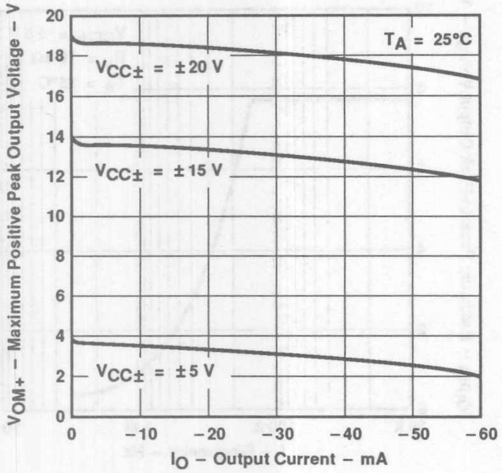


Figure 8

MAXIMUM NEGATIVE PEAK
OUTPUT VOLTAGE
vs
OUTPUT CURRENT

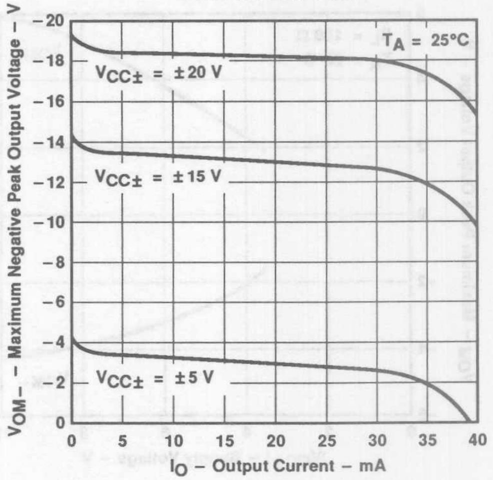


Figure 9

MAXIMUM PEAK OUTPUT VOLTAGE
vs
SUPPLY VOLTAGE

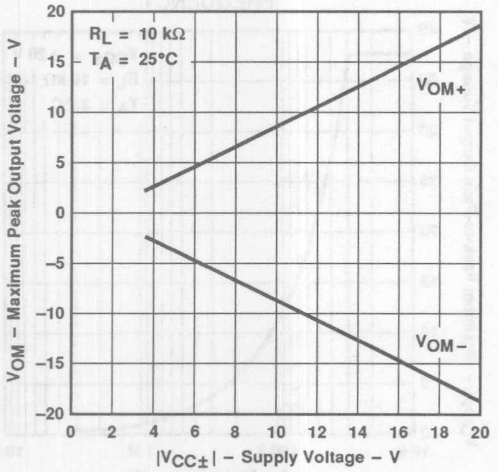


Figure 10

MAXIMUM PEAK OUTPUT VOLTAGE
vs
SUPPLY VOLTAGE

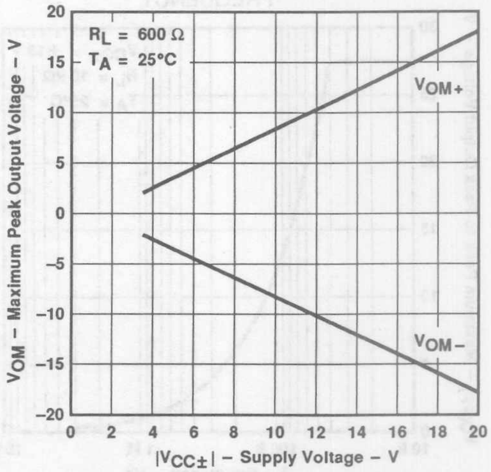


Figure 11

## TYPICAL CHARACTERISTICS

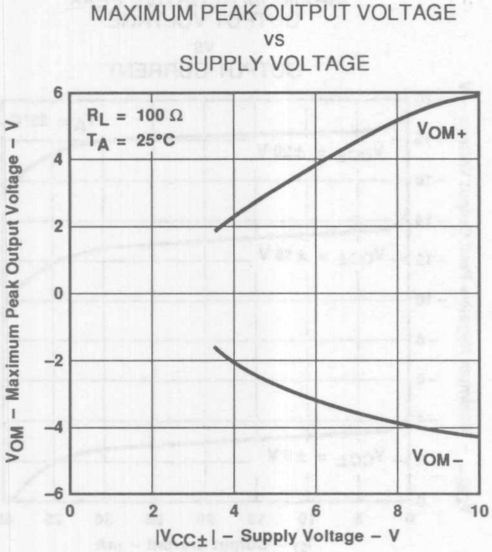


Figure 12

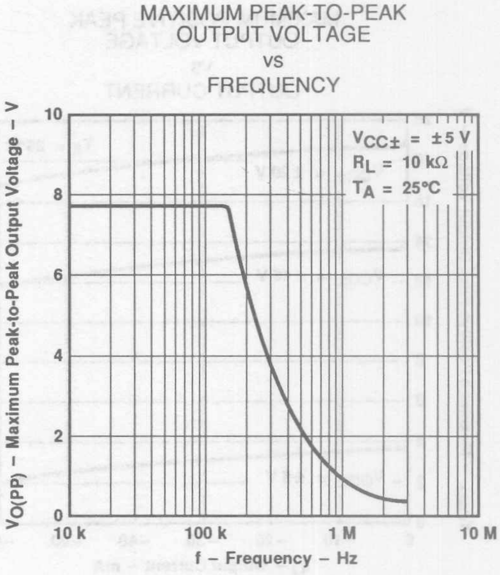


Figure 13

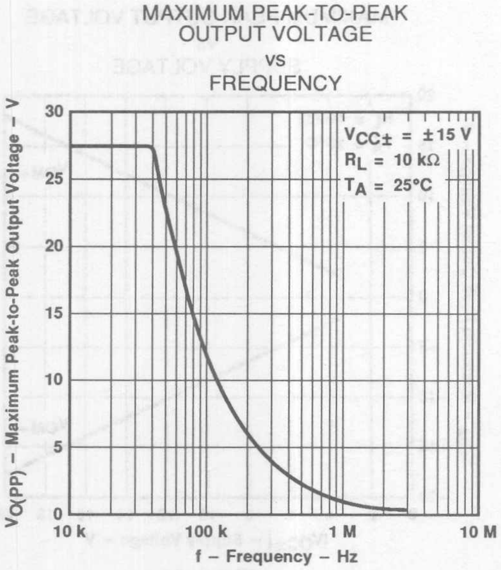


Figure 14

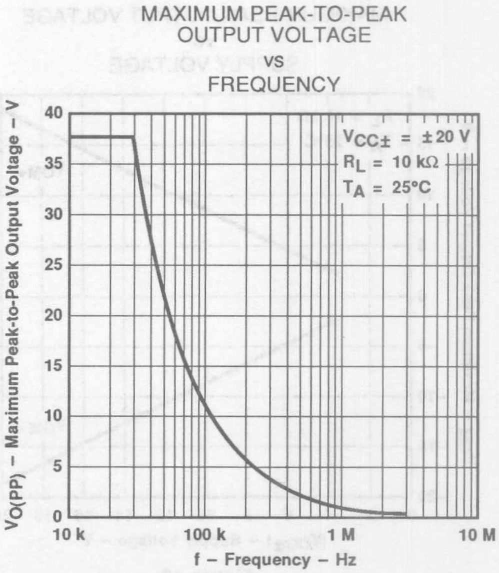


Figure 15

## TYPICAL CHARACTERISTICS†

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION and PHASE SHIFT
vs
FREQUENCY

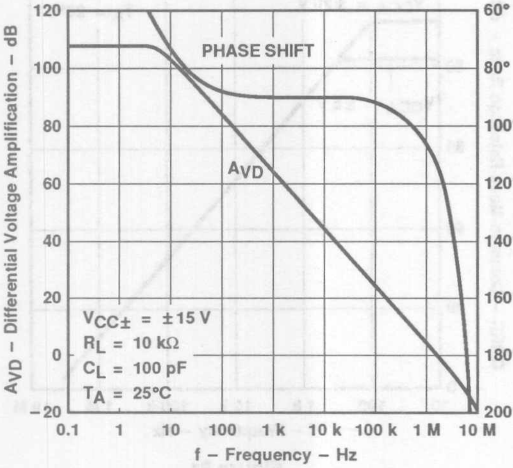


Figure 16

LARGE-SIGNAL VOLTAGE AMPLIFICATION
vs
FREE-AIR TEMPERATURE

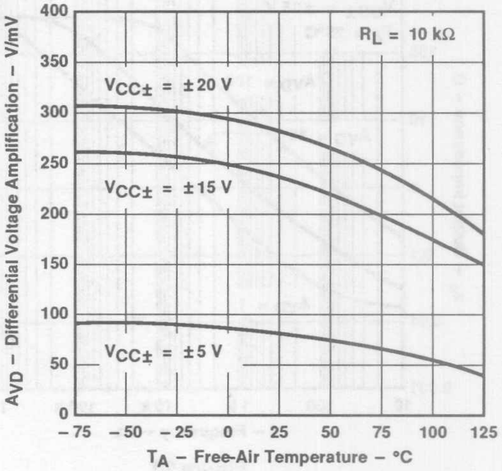


Figure 17

SHORT-CIRCUIT OUTPUT CURRENT
vs
ELAPSED TIME

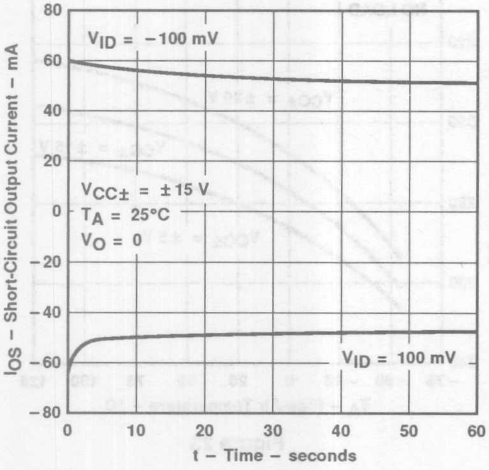


Figure 18

SHORT-CIRCUIT OUTPUT CURRENT
vs
FREE-AIR TEMPERATURE

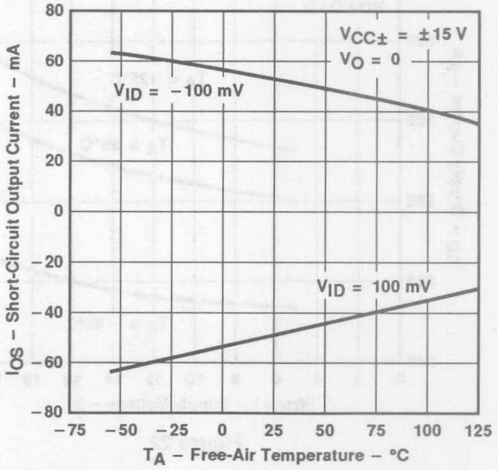


Figure 19

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†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS[†]

OUTPUT IMPEDANCE
vs
FREQUENCY

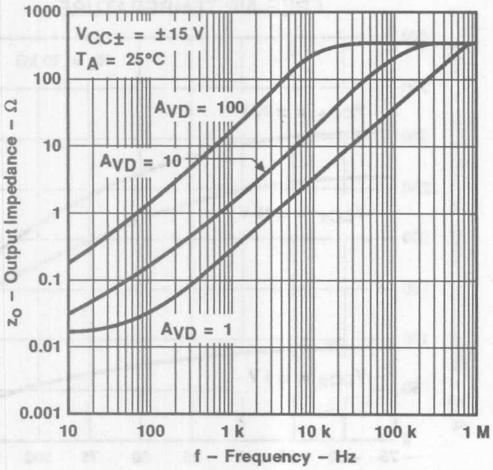


Figure 20

COMMON-MODE REJECTION RATIO
vs
FREQUENCY

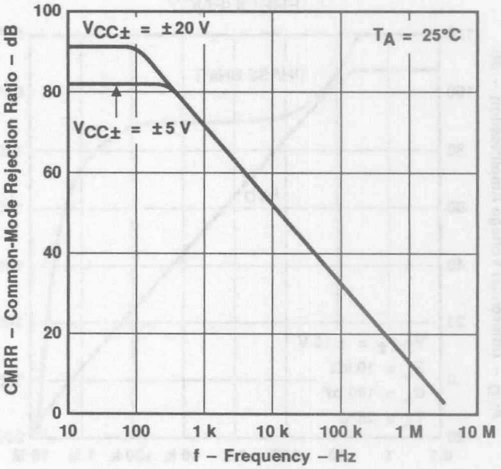


Figure 21

SUPPLY CURRENT
vs
SUPPLY VOLTAGE

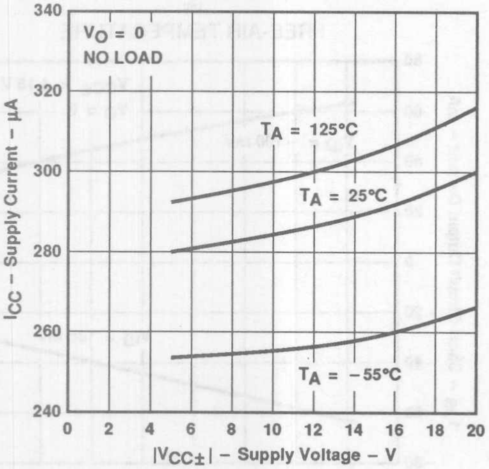


Figure 22

SUPPLY CURRENT
vs
FREE-AIR TEMPERATURE

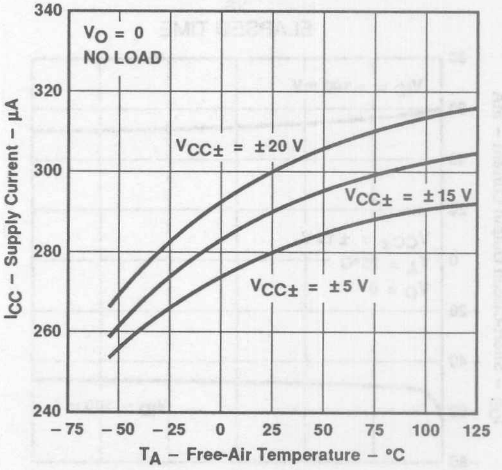


Figure 23

---

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS

VOLTAGE-FOLLOWER
SMALL-SIGNAL
PULSE RESPONSE

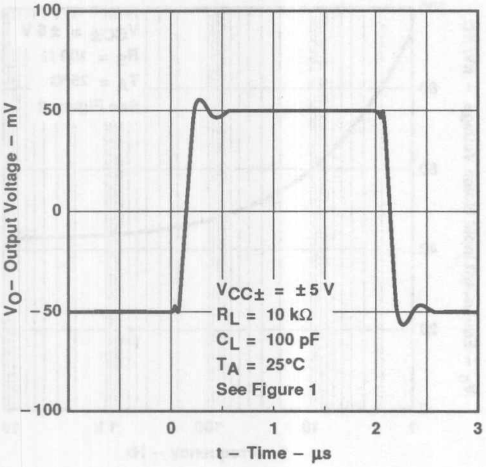


Figure 24

VOLTAGE-FOLLOWER
SMALL-SIGNAL
PULSE RESPONSE

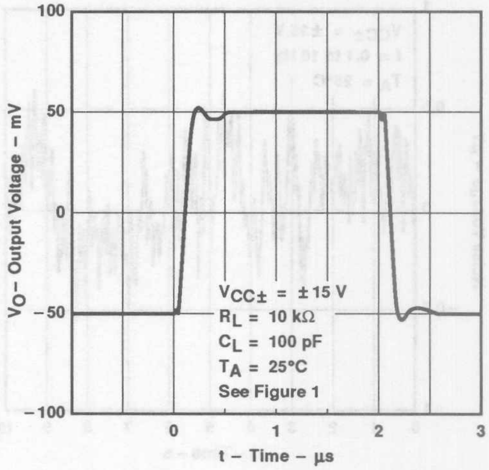


Figure 25

VOLTAGE-FOLLOWER
LARGE-SIGNAL
PULSE RESPONSE

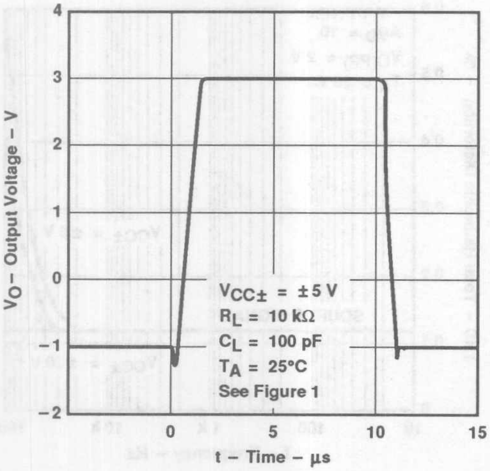


Figure 26

VOLTAGE-FOLLOWER
LARGE-SIGNAL
PULSE RESPONSE

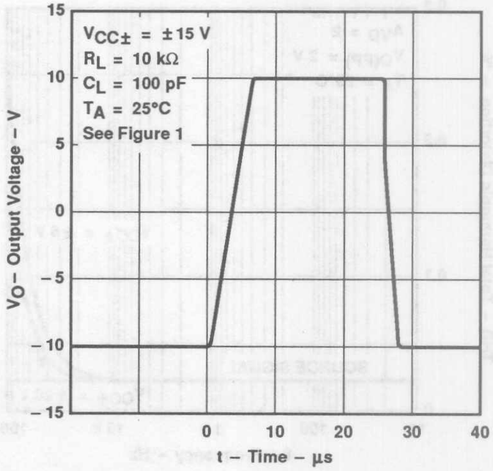


Figure 27

## TYPICAL CHARACTERISTICS

NOISE VOLTAGE
(REFERRED TO INPUT)
OVER A 10-SECOND INTERVAL

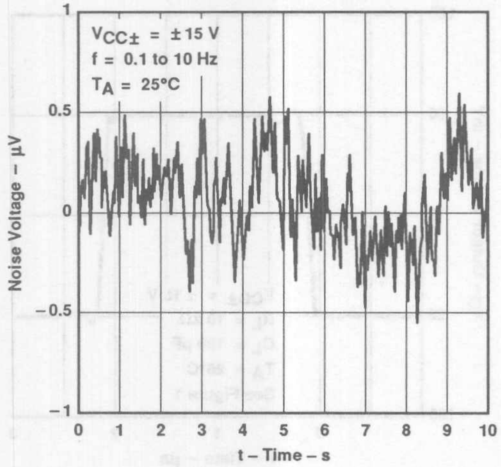


Figure 28

EQUIVALENT INPUT NOISE VOLTAGE
vs
FREQUENCY

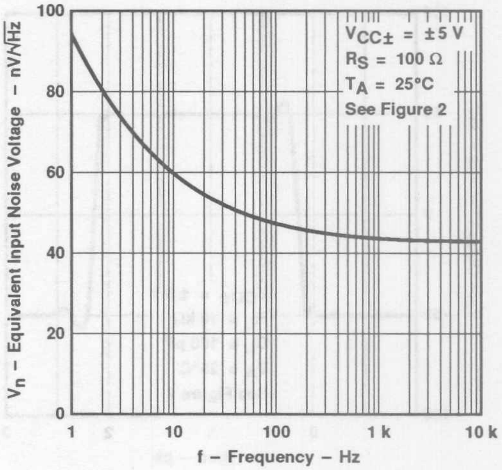


Figure 29

TOTAL HARMONIC DISTORTION
vs
FREQUENCY

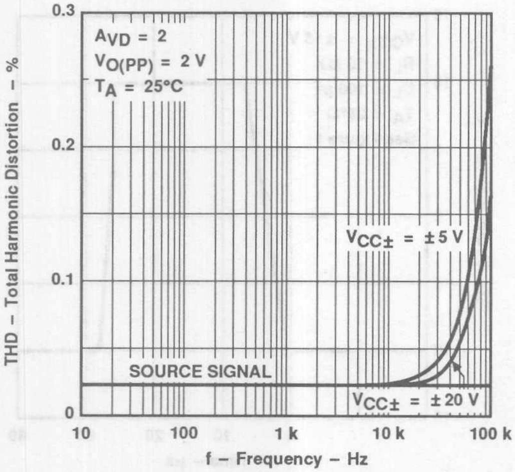


Figure 30

TOTAL HARMONIC DISTORTION
vs
FREQUENCY

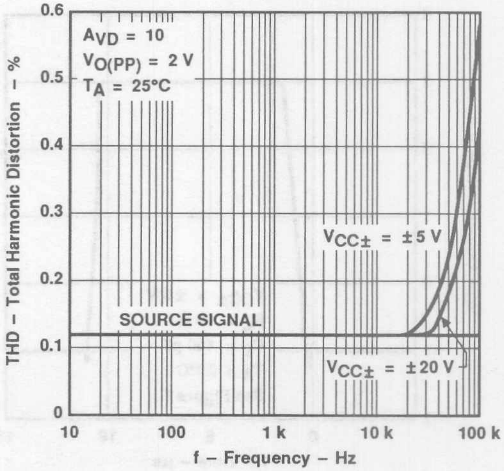


Figure 31

## TYPICAL CHARACTERISTICS†

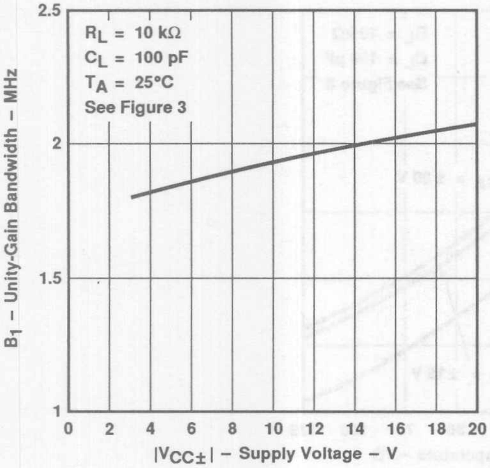

UNITY-GAIN BANDWIDTH
vs
SUPPLY VOLTAGE

Figure 32

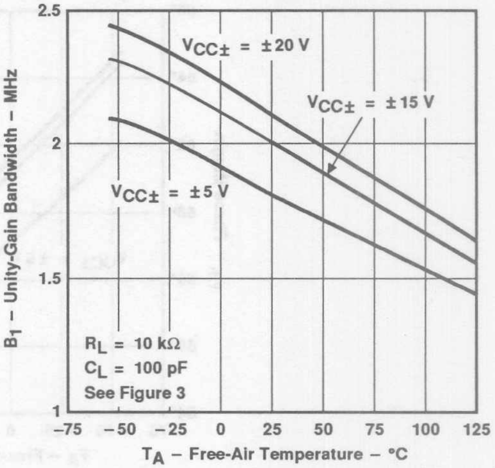

UNITY-GAIN BANDWIDTH
vs
FREE-AIR TEMPERATURE

Figure 33

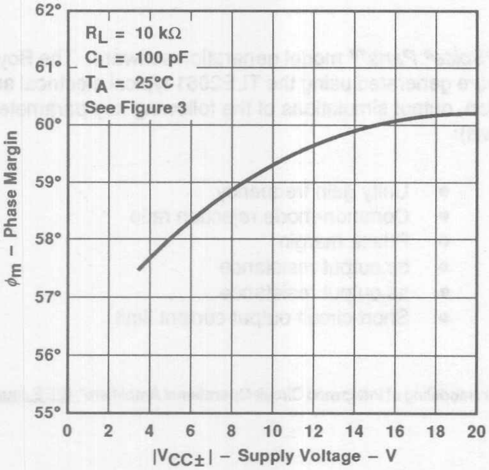

PHASE MARGIN
vs
SUPPLY VOLTAGE

Figure 34

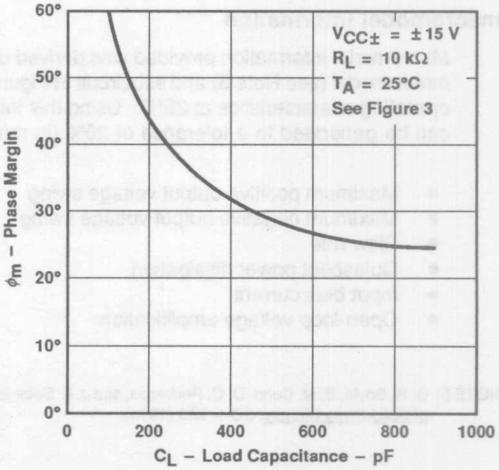

PHASE MARGIN
vs
LOAD CAPACITANCE

Figure 35

---

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

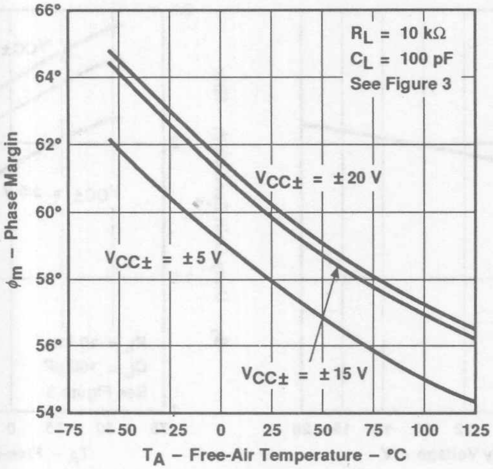

PHASE MARGIN
vs
FREE-AIR TEMPERATURE

Figure 36

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## APPLICATION INFORMATION

### macromodel information

Macromodel information provided was derived using *PSpice® Parts™* model generation software. The Boyle macromodel (see Note 5) and subcircuit in Figure 37 were generated using the TLE2061 typical electrical and operating characteristics at 25°C. Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

- Maximum positive output voltage swing
- Maximum negative output voltage swing
- Slew rate
- Quiescent power dissipation
- Input bias current
- Open-loop voltage amplification
- Unity gain frequency
- Common-mode rejection ratio
- Phase margin
- dc output resistance
- ac output resistance
- Short-circuit output current limit

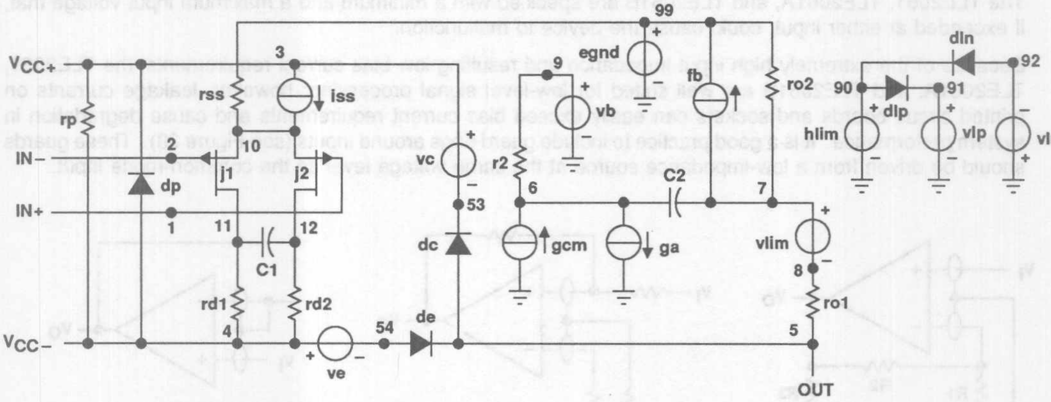
NOTE 5: G. R. Boyle, B. M. Cohn, D. O. Pederson, and J. E. Solomon, "Macromodeling of Integrated Circuit Operational Amplifiers", IEEE Journal of Solid-State Circuits, SC-9, 353 (1974).

*Parts* is a trademark of MicroSim Corporation.
*PSpice* is a registered trademark of MicroSim Corporation.

**Macromodels, simulation models, or other models provided by TI, directly or indirectly, are not warranted by TI as fully representing all of the specifications and operating characteristics of the semiconductor product to which the model relates.**

## APPLICATION INFORMATION

### macromodel information (continued)



```
.subckt TLE2061  1 2 3 4 5
  c1   11 12 1.457E-12
  c2    6  7 15.00E-12
  dc    5 53 dx
  de   54  5 dx
  dlp  90 91 dx
  dln  92 90 dx
  dp    4  3 dx
  egnd 99  0 poly(2) (3,0) (4,0) 0 .5 .5
  fb    7 99 poly(5) vb vc ve vlp vln 0 4.357E6 -4E6 4E6 4E6 -4E6
  ga    6  0 11 12 188.5E-6
  gcm   0  6 10 99 3.352E-9
  iss   3 10 dc 51.00E-6
  hlim 90  0 vlim 1K
  j1   11  2 10 jx
  j2   12  1 10 jx
  r2    6  9 100.0E3
  rd1   4 11 5.305E3
  rd2   4 12 5.305E3
  ro1   8  5 280
  ro2   7 99 280
  rp    3  4 113.2E3
  rss  10 99 3.922E6
  vb    9  0 dc 0
  vc    3 53 dc 2
  ve   54  4 dc 2
  vlim  7  8 dc 0
  vlp  91  0 dc 50
  vln   0 92 dc 50
.model dx D(Is=800.0E-18)
.model jx PJF(Is=2.000E-12 Beta=423E-6 Vto=-1)
.ends
```

Figure 37. Boyle Macromodel and Subcircuit

## APPLICATION INFORMATION

### input characteristics

The TLE2061, TLE2061A, and TLE2061B are specified with a minimum and a maximum input voltage that, if exceeded at either input, could cause the device to malfunction.

Because of the extremely high input impedance and resulting low bias current requirements, the TLE2061, TLE2061A, and TLE2061B are well suited for low-level signal processing; however, leakage currents on printed circuit boards and sockets can easily exceed bias current requirements and cause degradation in system performance. It is a good practice to include guard rings around inputs (see Figure 38). These guards should be driven from a low-impedance source at the same voltage level as the common-mode input.

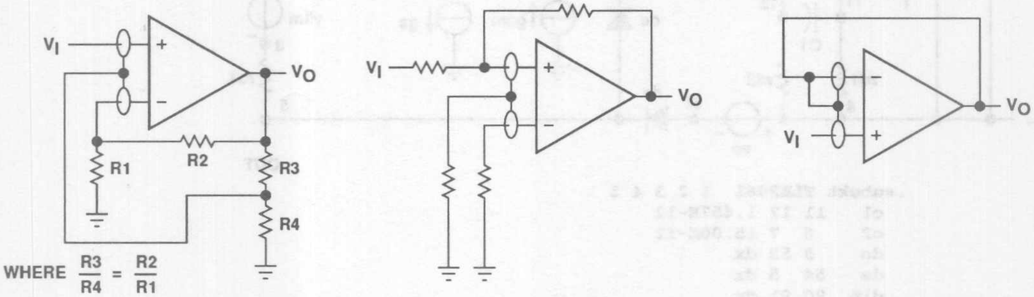


Figure 38. Use of Guard Rings

### input offset voltage nulling

The TLE2061 series offers external null pins that can be used to further reduce the input offset voltage. The circuit of Figure 39 can be connected as shown if the feature is desired. If external nulling is not needed, the null pins may be left disconnected.

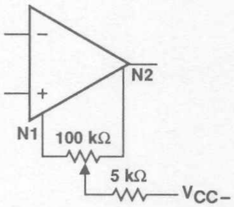


Figure 39. Input Offset Voltage Nulling

# TLE2062, TLE2062A, TLE2062B
# EXCALIBUR JFET-INPUT HIGH-OUTPUT-DRIVE µPOWER DUAL OPERATIONAL AMPLIFIERS

D3346, OCTOBER 1989 – REVISED JANUARY 1991

## available features

- **Excellent Output Drive Capability . . .**
  **$V_O$ = ± 2.5 V Min at $R_L$ = 100 Ω,**
  **$V_{CC\pm}$ = ± 5 V**
  **$V_O$ = ± 12.5 V Min at $R_L$ = 600 Ω,**
  **$V_{CC\pm}$ = ± 15 V**
- **Low Supply Current . . . 280 µA Typ Per Amplifier**
- **High Unity-Gain Bandwidth . . . 2.1 MHz Typ**
- **High Slew Rate . . . 3.4 V/µs Typ**
- **Macromodels Included**
- **Wide Operating Supply Voltage Range . . . $V_{CC\pm}$ = ± 3.5 V to ± 20 V**
- **High Open-Loop Gain . . . 280 V/mV Typ**
- **Low Offset Voltage . . . 1 mV Max**
- **Low Offset Voltage Drift With Time . . . 0.04 µV/mo Typ**
- **Low Input Bias Current . . . 5 pA Typ**

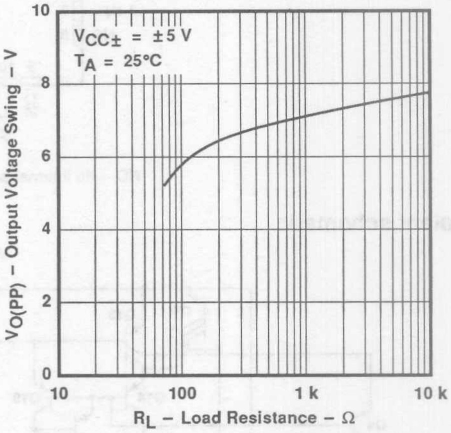
## description

The TLE2062, TLE2062A, and TLE2062B are JFET-input, low-power, precision operational amplifiers manufactured using Texas Instruments Excalibur process. These devices combine outstanding output drive capability with low-power consumption, excellent dc precision, and wide bandwidth.

In addition to maintaining the traditional JFET advantages of fast slew rates and low input bias and offset currents, the Excalibur process offers outstanding parametric stability over time and temperature. This results in a "precision" device remaining precise even with changes in temperature and over years of use.

The TLE2062, TLE2062A, and TLE2062B are ideal choices for any application requiring excellent dc precision, high output drive, wide bandwidth, and low power consumption.

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE SWING
vs
LOAD RESISTANCE



AVAILABLE OPTIONS

| $T_A$ | $V_{IO}$ max AT 25°C | PACKAGE | | | | |
|---|---|---|---|---|---|---|
| | | SMALL-OUTLINE (D) | CHIP CARRIER (FK) | CERAMIC DIP (JG) | METAL CAN (L) | PLASTIC DIP (P) |
| 0°C | 1 mV | — | — | — | — | TLE2062BCP |
| to | 2 mV | TLE2062ACD | — | — | — | TLE2062ACP |
| 70°C | 4 mV | TLE2062CD | — | — | — | TLE2062CP |
| – 40°C | 1 mV | — | — | — | — | TLE2062BIP |
| to | 2 mV | TLE2062AID | — | — | — | TLE2062AIP |
| 85°C | 4 mV | TLE2062ID | — | — | — | TLE2062IP |
| – 55°C | 1 mV | — | — | TLE2062BMJG | TLE2062BML | TLE2062BMP |
| to | 2 mV | TLE2062AMD | TLE2062AMFK | TLE2062AMJG | TLE2062AML | TLE2062AMP |
| 125°C | 4 mV | TLE2062MD | TLE2062MFK | TLE2062MJG | TLE2062ML | TLE2062MP |

D packages are available taped and reeled. Add "R" suffix to device type, (e.g., TLE2062ACDR).

PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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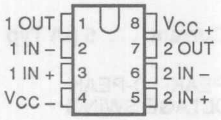
## description (continued)

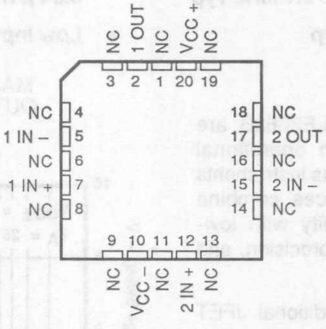
A variety of available package options includes small-outline and chip carrier versions for high-density system applications.

The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from −40°C to 85°C. The M-suffix devices are characterized for operation over the full military temperature range of −55°C to 125°C.

**D, JG, OR P PACKAGE**
**(TOP VIEW)**

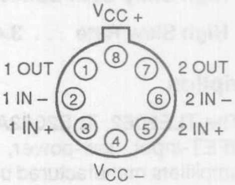


**FK PACKAGE**
**(TOP VIEW)**



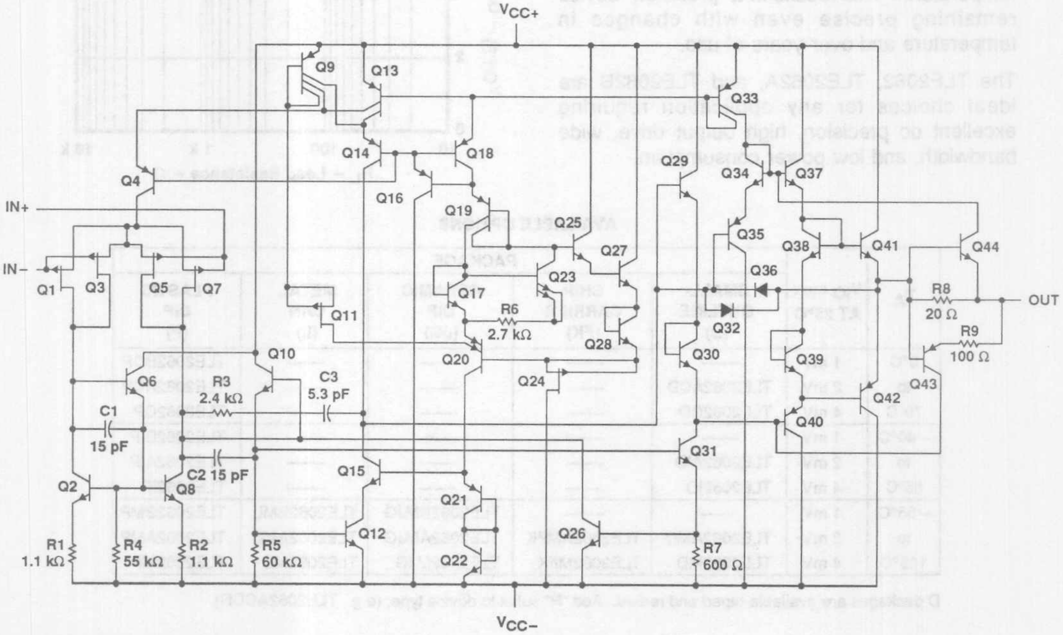
NC – No internal connection

**L PACKAGE**
**(TOP VIEW)**



Pin 4 of the L package is in electrical contact with the case.

## equivalent schematic



Component values are nominal.

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|---|
| Supply voltage, $V_{CC+}$ (see Note 1) | 22 V |
| Supply voltage, $V_{CC-}$ | −22 V |
| Differential input voltage (see Note 2) | ±44 V |
| Input voltage range, $V_I$ (any input) | $V_{CC\pm}$ |
| Input current, $I_I$ (each input) | ±1 mA |
| Output current, $I_O$ (each output) | ±80 mA |
| Total current into $V_{CC+}$ terminal | 80 mA |
| Total current out of $V_{CC-}$ terminal | 80 mA |
| Duration of short-circuit current at (or below) 25°C (see Note 3) | unlimited |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range, $T_A$: C-suffix | 0°C to 70°C |
| I-suffix | −40°C to 85°C |
| M-suffix | −55°C to 125°C |
| Storage temperature range | −65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG or L package | 300°C |

NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between $V_{CC+}$ and $V_{CC-}$.
2. Differential voltages are at the noninverting input with respect to the inverting input.
3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

### DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25°C$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25°C$ | $T_A = 70°C$ POWER RATING | $T_A = 85°C$ POWER RATING | $T_A = 125°C$ POWER RATING |
|---|---|---|---|---|---|
| D | 725 mW | 5.8 mW/°C | 464 mW | 377 mW | 145 mW |
| FK | 1375 mW | 11.0 mW/°C | 880 mW | 715 mW | 275 mW |
| JG | 1050 mW | 8.4 mW/°C | 672 mW | 546 mW | 210 mW |
| L | 650 mW | 5.2 mW/°C | 416 mW | 338 mW | 130 mW |
| P | 1000 mW | 8.0 mW/°C | 640 mW | 520 mW | 200 mW |

## recommended operating conditions

| | | C-SUFFIX | | I-SUFFIX | | M-SUFFIX | | UNIT |
|---|---|---|---|---|---|---|---|---|
| | | MIN | MAX | MIN | MAX | MIN | MAX | |
| Supply voltage, $V_{CC\pm}$ | | ± 3.5 | ± 20 | ± 3.5 | ± 20 | ± 3.5 | ± 20 | V |
| Common-mode input voltage, $V_{IC}$ | $V_{CC\pm} = \pm 5$ V | − 1.6 | 4 | − 1.6 | 4 | − 1.6 | 4 | V |
| | $V_{CC\pm} = \pm 15$ V | − 11 | 13 | − 11 | 13 | − 11 | 13 | |
| | $V_{CC\pm} = \pm 20$ V | − 15 | 16.5 | − 15 | 16.5 | − 15 | 16.5 | |
| Operating free-air temperature, $T_A$ | | 0 | 70 | − 40 | 85 | − 55 | 125 | °C |

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 5$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2062C | $V_{IC} = 0$, | $R_S = 50\ \Omega$ | 25°C | | 1 | 5 | mV |
| | | | | | Full range | | | 5.9 | |
| | | TLE2062AC | | | 25°C | | 0.9 | 4 | |
| | | | | | Full range | | | 4.9 | |
| | | TLE2062BC | | | 25°C | | 0.7 | 3 | |
| | | | | | Full range | | | 3.9 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | | Full range | | 6 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | | 25°C | | 0.04 | | µV/mo |
| $I_{IO}$ | Input offset current | | | | 25°C | | 1 | | pA |
| | | | | | Full range | | | 0.8 | nA |
| $I_{IB}$ | Input bias current | | | | 25°C | | 3 | | pA |
| | | | | | Full range | | | 2 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | | 25°C | −1.6 to 4 | −2 to 6 | | V |
| | | | | | Full range | −1.6 to 4 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | | 25°C | 3.5 | 3.7 | | V |
| | | | | | Full range | 3.3 | | | |
| | | | $R_L = 100\ \Omega$ | | 25°C | 2.5 | 3.1 | | |
| | | | | | Full range | 2 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | | 25°C | −3.7 | −3.9 | | V |
| | | | | | Full range | −3.3 | | | |
| | | | $R_L = 100\ \Omega$ | | 25°C | −2.5 | −2.7 | | |
| | | | | | Full range | −2 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 2.8$ V, | $R_L = 10\ k\Omega$ | 25°C | 15 | 80 | | V/mV |
| | | | | | Full range | 2 | | | |
| | | | $V_O = 0$ to 2 V, | $R_L = 100\ \Omega$ | 25°C | 0.75 | 45 | | |
| | | | | | Full range | 0.5 | | | |
| | | | $V_O = 0$ to −2 V, | $R_L = 100\ \Omega$ | 25°C | 0.5 | 3 | | |
| | | | | | Full range | 0.25 | | | |
| $r_i$ | Input resistance | | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | | 25°C | | 560 | | Ω |
| CMRR | Common-mode rejection ratio | | $R_S = 50\ \Omega$,<br>$V_{IC} = V_{ICR}$ min | | 25°C | 65 | 82 | | dB |
| | | | | | Full range | 65 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to $\pm 20$ V,<br>$R_S = 50\ \Omega$ | | 25°C | 75 | 93 | | dB |
| | | | | | Full range | 75 | | | |
| $I_{CC}$ | Supply current (two amplifiers) | | $V_O = 0$, | No load | 25°C | | 560 | 620 | µA |
| | | | | | Full range | | | 635 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range (two amplifiers) | | | | Full range | | 26 | | µA |

† Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150$°C extrapolated to $T_A = 25$°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | 2.2 | 3.4 | | V/µs |
| | | | | Full range | 2.1 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S$ = 100 Ω | 25°C | | 59 | 100 | nV/√Hz |
| | | f = 1 kHz, | $R_S$ = 100 Ω | 25°C | | 43 | 60 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | 25°C | | 1.1 | | µV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | 25°C | | 1 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD}$ = 2,<br>$V_{O(PP)}$ = 2 V, | f = 10 kHz,<br>$R_L$ = 10 kΩ | 25°C | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 1.8 | | MHz |
| | | $R_L$ = 100 Ω, | $C_L$ = 100 pF | 25°C | | 1.3 | | |
| | Settling time | 0.1% | | 25°C | | 5 | | µs |
| | | 0.01% | | 25°C | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD}$ = 1, | $R_L$ = 10 kΩ | 25°C | | 140 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 58° | | |
| | | $R_L$ = 100 Ω, | $C_L$ = 100 pF | 25°C | | 75° | | |

†Full range is 0°C to 70°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2062C | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 0.9 | 4 | mV |
| | | | | Full range | | | 4.9 | |
| | | TLE2062AC | | 25°C | | 0.8 | 2 | |
| | | | | Full range | | | 2.9 | |
| | | TLE2062BC | | 25°C | | 0.5 | 1 | |
| | | | | Full range | | | 1.9 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | µV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 2 | | pA |
| | | | | Full range | | | 1 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 4 | | pA |
| | | | | Full range | | | 3 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | − 11 to 13 | − 12 to 16 | | V |
| | | | | Full range | − 11 to 13 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 13.2 | 13.7 | | V |
| | | | | Full range | 13 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | 12.5 | 13.2 | | |
| | | | | Full range | 12 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | − 13.2 | − 13.7 | | V |
| | | | | Full range | − 13 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | − 12.5 | − 13 | | |
| | | | | Full range | − 12 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 10$ V, $R_L = 10\ k\Omega$ | 25°C | 30 | 230 | | V/mV |
| | | | | Full range | 20 | | | |
| | | | $V_O = 0$ to 8 V, $R_L = 600\ \Omega$ | 25°C | 25 | 100 | | |
| | | | | Full range | 10 | | | |
| | | | $V_O = 0$ to − 8 V, $R_L = 600\ \Omega$ | 25°C | 3 | 25 | | |
| | | | | Full range | 1 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | 25°C | | 560 | | Ω |
| CMRR | Common-mode rejection ratio | | $R_S = 50\ \Omega$,<br>$V_{IC} = V_{ICR}$ min | 25°C | 72 | 90 | | dB |
| | | | | Full range | 70 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to $\pm 15$ V,<br>$R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | | | Full range | 75 | | | |
| $I_{CC}$ | Supply current (two amplifiers) | | $V_O = 0$, No load | 25°C | | 625 | 690 | µA |
| | | | | Full range | | | 715 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range (two amplifiers) | | | Full range | | 36 | | µA |

† Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | 2.6 | 3.4 | | V/µs |
| | | | | Full range | 2.5 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S$ = 100 Ω | 25°C | | 70 | 100 | nV/√Hz |
| | | f = 1 kHz, | $R_S$ = 100 Ω | 25°C | | 40 | 60 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | 25°C | | 1.1 | | µV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | 25°C | | 1.1 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD}$ = 2,<br>$V_{O(PP)}$ = 2 V, | f = 10 kHz,<br>$R_L$ = 10 kΩ | 25°C | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 2 | | MHz |
| | | $R_L$ = 600 Ω, | $C_L$ = 100 pF | 25°C | | 1.5 | | |
| | Settling time | 0.1% | | 25°C | | 5 | | µs |
| | | 0.01% | | 25°C | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD}$ = 1, | $R_L$ = 10 kΩ | 25°C | | 40 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 60° | | |
| | | $R_L$ = 600 Ω, | $C_L$ = 100 pF | 25°C | | 70° | | |

†Full range is 0°C to 70°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 20$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2062C | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 0.9 | 4 | mV |
| | | | | Full range | | | 4.9 | |
| | | TLE2062AC | | 25°C | | 0.8 | 2.6 | |
| | | | | Full range | | | 3.5 | |
| | | TLE2062BC | | 25°C | | 0.5 | 1.7 | |
| | | | | Full range | | | 2.6 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | µV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 3 | | pA |
| | | | | Full range | | | 1 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 5 | | pA |
| | | | | Full range | | | 3 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | − 15<br>to<br>16.5 | − 17<br>to<br>21 | | V |
| | | | | Full range | − 15<br>to<br>16.5 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 18.2 | 18.7 | | V |
| | | | | Full range | 18 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | 15 | 18.1 | | |
| | | | | Full range | 12 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | − 18.2 | − 18.7 | | V |
| | | | | Full range | − 18 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | − 15 | − 18 | | |
| | | | | Full range | − 12 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 15$ V, $R_L = 10\ k\Omega$ | 25°C | 30 | 280 | | V/mV |
| | | | | Full range | 20 | | | |
| | | | $V_O = 0$ to 10 V, $R_L = 600\ \Omega$ | 25°C | 25 | 80 | | |
| | | | | Full range | 10 | | | |
| | | | $V_O = 0$ to − 10 V, $R_L = 600\ \Omega$ | 25°C | 3 | 20 | | |
| | | | | Full range | 1 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | 25°C | | 560 | | Ω |
| CMRR | Common-mode rejection ratio | | $R_S = 50\ \Omega$,<br>$V_{IC} = V_{ICR}$ min | 25°C | 75 | 91 | | dB |
| | | | | Full range | 70 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to $\pm 20$ V,<br>$R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | | | Full range | 70 | | | |
| $I_{CC}$ | Supply current (two amplifiers) | | $V_O = 0$, No load | 25°C | | 660 | 730 | µA |
| | | | | Full range | | | 750 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range (two amplifiers) | | | Full range | | 41 | | µA |

† Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 20$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | 2.8 | 3.4 | | V/µs |
| | | | | Full range | 2.5 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S$ = 100 Ω | 25°C | | 75 | 100 | nV/√Hz |
| | | f = 1 kHz, | $R_S$ = 100 Ω | 25°C | | 40 | 60 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | 25°C | | 1.1 | | µV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | 25°C | | 1.3 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD}$ = 2,<br>$V_{O(PP)}$ = 2 V, | f = 10 kHz,<br>$R_L$ = 10 kΩ | 25°C | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 2.1 | | MHz |
| | | $R_L$ = 600 Ω, | $C_L$ = 100 pF | 25°C | | 1.6 | | |
| | Settling time | 0.1% | | 25°C | | 5 | | µs |
| | | 0.01% | | 25°C | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD}$ = 1, | $R_L$ = 10 kΩ | 25°C | | 28 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 60° | | |
| | | $R_L$ = 600 Ω, | $C_L$ = 100 pF | 25°C | | 70° | | |

†Full range is 0°C to 70°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm}$ = ±5 V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2062I | $V_{IC}$ = 0, $R_S$ = 50 Ω | 25°C | | 1 | 5 | mV |
| | | | | Full range | | | 6.3 | |
| | | TLE2062AI | | 25°C | | 0.9 | 4 | |
| | | | | Full range | | | 5.3 | |
| | | TLE2062BI | | 25°C | | 0.7 | 3 | |
| | | | | Full range | | | 4.3 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | µV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 1 | | pA |
| | | | | Full range | | | 2 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 3 | | pA |
| | | | | Full range | | | 4 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | −1.6 to 4 | −2 to 6 | | V |
| | | | | Full range | −1.6 to 4 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L$ = 10 kΩ | 25°C | 3.5 | 3.7 | | V |
| | | | | Full range | 3.1 | | | |
| | | | $R_L$ = 100 Ω | 25°C | 2.5 | 3.1 | | |
| | | | | Full range | 2 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L$ = 10 kΩ | 25°C | −3.7 | −3.9 | | V |
| | | | | Full range | −3.1 | | | |
| | | | $R_L$ = 100 Ω | 25°C | −2.5 | −2.7 | | |
| | | | | Full range | −2 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O$ = ±2.8 V, $R_L$ = 10 kΩ | 25°C | 15 | 80 | | V/mV |
| | | | | Full range | 2 | | | |
| | | | $V_O$ = 0 to 2 V, $R_L$ = 100 Ω | 25°C | 0.75 | 45 | | |
| | | | | Full range | 0.5 | | | |
| | | | $V_O$ = 0 to −2 V, $R_L$ = 100 Ω | 25°C | 0.5 | 3 | | |
| | | | | Full range | 0.25 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O$ = 0 | 25°C | | 560 | | Ω |
| CMRR | Common-mode rejection ratio | | $R_S$ = 50 Ω,<br>$V_{IC}$ = $V_{ICR}$ min | 25°C | 65 | 82 | | dB |
| | | | | Full range | 65 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$) | | $V_{CC\pm}$ = ±5 V to ±20 V,<br>$R_S$ = 50 Ω | 25°C | 75 | 93 | | dB |
| | | | | Full range | 65 | | | |
| $I_{CC}$ | Supply current (two amplifiers) | | $V_O$ = 0, No load | 25°C | | 560 | 620 | µA |
| | | | | Full range | | | 640 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range (two amplifiers) | | | Full range | | 54 | | µA |

†Full range is – 40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A$ = 150°C extrapolated to $T_A$ = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L = 10\ \text{k}\Omega$, | $C_L = 100$ pF | 25°C | 2.2 | 3.4 | | V/μs |
| | | | | Full range | 1.7 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S = 100\ \Omega$ | 25°C | | 59 | 100 | nV/√Hz |
| | | f = 1 kHz, | $R_S = 100\ \Omega$ | 25°C | | 43 | 60 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | 25°C | | 1.1 | | μV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | 25°C | | 1 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD} = 2$,<br>$V_{O(PP)} = 2$ V, | f = 10 kHz,<br>$R_L = 10\ \text{k}\Omega$ | 25°C | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L = 10\ \text{k}\Omega$, | $C_L = 100$ pF | 25°C | | 1.8 | | MHz |
| | | $R_L = 100\ \Omega$, | $C_L = 100$ pF | 25°C | | 1.3 | | |
| | Settling time | 0.1% | | 25°C | | 5 | | μs |
| | | 0.01% | | 25°C | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD} = 1$, | $R_L = 10\ \text{k}\Omega$ | 25°C | | 140 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L = 10\ \text{k}\Omega$, | $C_L = 100$ pF | 25°C | | 58° | | |
| | | $R_L = 100\ \Omega$, | $C_L = 100$ pF | 25°C | | 75° | | |

†Full range is – 40°C to 85°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2062I | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 0.9 | 4 | mV |
| | | | | Full range | | | 5.3 | |
| | | TLE2062AI | | 25°C | | 0.8 | 2 | |
| | | | | Full range | | | 3.3 | |
| | | TLE2062BI | | 25°C | | 0.5 | 1 | |
| | | | | Full range | | | 2.3 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | µV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 2 | | pA |
| | | | | Full range | | | 3 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 4 | | pA |
| | | | | Full range | | | 5 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | − 11 to 13 | − 12 to 16 | | V |
| | | | | Full range | − 11 to 13 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 13.2 | 13.7 | | V |
| | | | | Full range | 13 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | 12.5 | 13.2 | | |
| | | | | Full range | 12 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | − 13.2 | − 13.7 | | V |
| | | | | Full range | − 13 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | − 12.5 | − 13 | | |
| | | | | Full range | − 12 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 10$ V, $R_L = 10\ k\Omega$ | 25°C | 30 | 230 | | V/mV |
| | | | | Full range | 20 | | | |
| | | | $V_O = 0$ to 8 V, $R_L = 600\ \Omega$ | 25°C | 25 | 100 | | |
| | | | | Full range | 10 | | | |
| | | | $V_O = 0$ to − 8 V, $R_L = 600\ \Omega$ | 25°C | 3 | 25 | | |
| | | | | Full range | 1 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | 25°C | | 560 | | Ω |
| CMRR | Common-mode rejection ratio | | $R_S = 50\ \Omega$,<br>$V_{IC} = V_{ICR}$ min | 25°C | 72 | 90 | | dB |
| | | | | Full range | 65 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to $\pm 15$ V,<br>$R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | | | Full range | 65 | | | |
| $I_{CC}$ | Supply current (two amplifiers) | | $V_O = 0$, No load | 25°C | | 625 | 690 | µA |
| | | | | Full range | | | 720 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range (two amplifiers) | | | Full range | | 74 | | µA |

†Full range is – 40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L = 10$ kΩ, | $C_L = 100$ pF | 25°C | 2.6 | 3.4 | | V/μs |
| | | | | Full range | 2.1 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S = 100\ \Omega$ | 25°C | | 70 | 100 | nV/√Hz |
| | | f = 1 kHz, | $R_S = 100\ \Omega$ | 25°C | | 40 | 60 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | 25°C | | 1.1 | | μV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | 25°C | | 1.1 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD} = 2$,<br>$V_{O(PP)} = 2$ V, | f = 10 kHz,<br>$R_L = 10$ kΩ | 25°C | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L = 10$ kΩ, | $C_L = 100$ pF | 25°C | | 2 | | MHz |
| | | $R_L = 600\ \Omega$, | $C_L = 100$ pF | 25°C | | 1.5 | | |
| | Settling time | 0.1% | | 25°C | | 5 | | μs |
| | | 0.01% | | 25°C | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD} = 1$, | $R_L = 10$ kΩ | 25°C | | 40 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L = 10$ kΩ, | $C_L = 100$ pF | 25°C | | 60° | | |
| | | $R_L = 600\ \Omega$, | $C_L = 100$ pF | 25°C | | 70° | | |

† Full range is – 40°C to 85°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 20$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2062I | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 0.9 | 4 | mV |
| | | | | Full range | | | 5.3 | |
| | | TLE2062AI | | 25°C | | 0.8 | 2.6 | |
| | | | | Full range | | | 3.9 | |
| | | TLE2062BI | | 25°C | | 0.5 | 1.7 | |
| | | | | Full range | | | 3 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | μV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | μV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 3 | | pA |
| | | | | Full range | | | 3 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 5 | | pA |
| | | | | Full range | | | 5 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | −15 to 16.5 | −17 to 21 | | V |
| | | | | Full range | −15 to 16.5 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 18.2 | 18.7 | | V |
| | | | | Full range | 18 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | 15 | 18.1 | | |
| | | | | Full range | 12 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | −18.2 | −18.7 | | V |
| | | | | Full range | −18 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | −15 | −18 | | |
| | | | | Full range | −12 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 15$ V, $R_L = 10\ k\Omega$ | 25°C | 30 | 280 | | V/mV |
| | | | | Full range | 20 | | | |
| | | | $V_O = 0$ to 10 V, $R_L = 600\ \Omega$ | 25°C | 25 | 80 | | |
| | | | | Full range | 10 | | | |
| | | | $V_O = 0$ to −10 V, $R_L = 600\ \Omega$ | 25°C | 3 | 20 | | |
| | | | | Full range | 1 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | 25°C | | 560 | | Ω |
| CMRR | Common-mode rejection ratio | | $R_S = 50\ \Omega$,<br>$V_{IC} = V_{ICR}$ min | 25°C | 75 | 91 | | dB |
| | | | | Full range | 65 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to $\pm 20$ V,<br>$R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | | | Full range | 65 | | | |
| $I_{CC}$ | Supply current (two amplifiers) | | $V_O = 0$, No load | 25°C | | 660 | 730 | μA |
| | | | | Full range | | | 755 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range (two amplifiers) | | | Full range | | 82 | | μA |

†Full range is – 40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 20$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L = 10\ k\Omega$, | $C_L = 100$ pF | 25°C | 2.8 | 3.4 | | V/μs |
| | | | | Full range | 2.1 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S = 100\ \Omega$ | 25°C | | 75 | 100 | nV/√Hz |
| | | f = 1 kHz, | $R_S = 100\ \Omega$ | 25°C | | 40 | 60 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | 25°C | | 1.1 | | μV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | 25°C | | 1.3 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD} = 2$,<br>$V_{O(PP)} = 2$ V, | f = 10 kHz,<br>$R_L = 10\ k\Omega$ | 25°C | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L = 10\ k\Omega$, | $C_L = 100$ pF | 25°C | | 2.1 | | MHz |
| | | $R_L = 600\ \Omega$, | $C_L = 100$ pF | 25°C | | 1.6 | | |
| | Settling time | 0.1% | | 25°C | | 5 | | μs |
| | | 0.01% | | 25°C | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD} = 1$, | $R_L = 10\ k\Omega$ | 25°C | | 28 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L = 10\ k\Omega$, | $C_L = 100$ pF | 25°C | | 60° | | |
| | | $R_L = 600\ \Omega$, | $C_L = 100$ pF | 25°C | | 70° | | |

† Full range is – 40°C to 85°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 5$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2062M | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 1 | 5 | mV |
| | | | | Full range | | | 7 | |
| | | TLE2062AM | | 25°C | | 0.9 | 4 | |
| | | | | Full range | | | 6 | |
| | | TLE2062BM | | 25°C | | 0.7 | 3 | |
| | | | | Full range | | | 5 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | µV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 1 | | pA |
| | | | | Full range | | | 15 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 3 | | pA |
| | | | | Full range | | | 30 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | −1.6<br>to<br>4 | −2<br>to<br>6 | | V |
| | | | | Full range | −1.6<br>to<br>4 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 3.5 | 3.7 | | V |
| | | | | Full range | 3 | | | |
| | | FK, JG, and L packages | $R_L = 600\ \Omega$ | 25°C | 2.5 | 3.6 | | |
| | | | | Full range | 2 | | | |
| | | D and P packages | $R_L = 100\ \Omega$ | 25°C | 2.5 | 3.1 | | |
| | | | | Full range | 2 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | −3.5 | −3.9 | | V |
| | | | | Full range | −3 | | | |
| | | FK, JG, and L packages | $R_L = 600\ \Omega$ | 25°C | −2.5 | −3.5 | | |
| | | | | Full range | −2 | | | |
| | | D and P packages | $R_L = 100\ \Omega$ | 25°C | −2.5 | −2.7 | | |
| | | | | Full range | −2 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 2.8$ V, $R_L = 10\ k\Omega$ | 25°C | 15 | 80 | | V/mV |
| | | | | Full range | 2 | | | |
| | | FK, JG, and L packages | $V_O = 0$ to 2.5 V, $R_L = 600\ \Omega$ | 25°C | 1 | 65 | | |
| | | | | Full range | 0.5 | | | |
| | | | $V_O = 0$ to −2.5 V, $R_L = 600\ \Omega$ | 25°C | 1 | 16 | | |
| | | | | Full range | 0.5 | | | |
| | | D and P packages | $V_O = 0$ to 2 V, $R_L = 100\ \Omega$ | 25°C | 0.75 | 45 | | |
| | | | | Full range | 0.5 | | | |
| | | | $V_O = 0$ to −2 V, $R_L = 100\ \Omega$ | 25°C | 0.5 | 3 | | |
| | | | | Full range | 0.25 | | | |

†Full range is – 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 5$ V (unless otherwise noted) (continued)

| | PARAMETER | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | $I_O = 0$ | | 25°C | | 560 | | Ω |
| CMRR | Common-mode rejection ratio | $R_S = 50\ \Omega$,<br>$V_{IC} = V_{ICR}$ min | | 25°C | 65 | 82 | | dB |
| | | | | Full range | 60 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 5$ V to $\pm 20$ V,<br>$R_S = 50\ \Omega$ | | 25°C | 75 | 93 | | dB |
| | | | | Full range | 65 | | | |
| $I_{CC}$ | Supply current (two amplifiers) | $V_O = 0$, | No load | 25°C | | 560 | 620 | µA |
| | | | | Full range | | | 650 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range (two amplifiers) | | | Full range | | 72 | | µA |

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 5$ V (unless otherwise noted)

| | PARAMETER | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L = 10\ k\Omega$, | $C_L = 100$ pF | 25°C | | 3.4 | | V/µs |
| | | | | Full range | | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S = 100\ \Omega$ | 25°C | | 59 | | nV/√Hz |
| | | f = 1 kHz, | $R_S = 100\ \Omega$ | 25°C | | 43 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | 25°C | | 1.1 | | µV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | 25°C | | 1 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD} = 2$,<br>$V_{O(PP)} = 2$ V, | f = 10 kHz,<br>$R_L = 10\ k\Omega$ | 25°C | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L = 10\ k\Omega$, | $C_L = 100$ pF | 25°C | | 1.8 | | MHz |
| | | $R_L = 600\ \Omega$, | $C_L = 100$ pF | 25°C | | 1.3 | | |
| | Settling time | 0.1% | | 25°C | | 5 | | µs |
| | | 0.01% | | 25°C | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD} = 1$, | $R_L = 10\ k\Omega$ | 25°C | | 140 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L = 10\ k\Omega$, | $C_L = 100$ pF | 25°C | | 58° | | |
| | | $R_L = 600\ \Omega$, | $C_L = 100$ pF | 25°C | | 75° | | |

† Full range is – 55°C to 125°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2062M | $V_{IC} = 0$, | $R_S = 50\ \Omega$ | 25°C | | 0.9 | 4 | mV |
| | | | | | Full range | | | 6 | |
| | | TLE2062AM | | | 25°C | | 0.8 | 2 | |
| | | | | | Full range | | | 4 | |
| | | TLE2062BM | | | 25°C | | 0.5 | 1 | |
| | | | | | Full range | | | 3 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | | Full range | | 6 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | | 25°C | | 0.04 | | µV/mo |
| $I_{IO}$ | Input offset current | | | | 25°C | | 2 | | pA |
| | | | | | Full range | | | 20 | nA |
| $I_{IB}$ | Input bias current | | | | 25°C | | 4 | | pA |
| | | | | | Full range | | | 40 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | | 25°C | −11<br>to<br>13 | −12<br>to<br>16 | | V |
| | | | | | Full range | −11<br>to<br>13 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | | 25°C | 13 | 13.7 | | V |
| | | | | | Full range | 12.5 | | | |
| | | | $R_L = 600\ \Omega$ | | 25°C | 12.5 | 13.2 | | |
| | | | | | Full range | 11 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | | 25°C | −13 | −13.7 | | V |
| | | | | | Full range | −12.5 | | | |
| | | | $R_L = 600\ \Omega$ | | 25°C | −12.5 | −13 | | |
| | | | | | Full range | −11 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 10$ V, | $R_L = 10\ k\Omega$ | 25°C | 30 | 230 | | V/mV |
| | | | | | Full range | 20 | | | |
| | | | $V_O = 0$ to 8 V, | $R_L = 600\ \Omega$ | 25°C | 25 | 100 | | |
| | | | | | Full range | 7 | | | |
| | | | $V_O = 0$ to −8 V, | $R_L = 600\ \Omega$ | 25°C | 3 | 25 | | |
| | | | | | Full range | 1 | | | |
| $r_i$ | Input resistance | | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | | 25°C | | 560 | | Ω |
| CMRR | Common-mode rejection ratio | | $R_S = 50\ \Omega$,<br>$V_{IC} = V_{ICR}$ min | | 25°C | 72 | 90 | | dB |
| | | | | | Full range | 65 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to ± 15 V,<br>$R_S = 50\ \Omega$ | | 25°C | 75 | 93 | | dB |
| | | | | | Full range | 65 | | | |
| $I_{CC}$ | Supply current (two amplifiers) | | $V_O = 0$, | No load | 25°C | | 625 | 690 | µA |
| | | | | | Full range | | | 730 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range (two amplifiers) | | | | Full range | | 97 | | µA |

†Full range is – 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150$°C extrapolated to $T_A = 25$°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L = 10\ k\Omega$, | $C_L = 100$ pF | 25°C | 2 | 3.4 | | V/µs |
| | | | | Full range | 1.8 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S = 100\ \Omega$ | 25°C | | 70 | | nV/√Hz |
| | | f = 1 kHz, | $R_S = 100\ \Omega$ | 25°C | | 40 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | 25°C | | 1.1 | | µV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | 25°C | | 1.1 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD} = 2$,<br>$V_{O(PP)} = 2$ V, | f = 10 kHz,<br>$R_L = 10\ k\Omega$ | 25°C | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L = 10\ k\Omega$, | $C_L = 100$ pF | 25°C | | 2 | | MHz |
| | | $R_L = 600\ \Omega$, | $C_L = 100$ pF | 25°C | | 1.5 | | |
| | Settling time | 0.1% | | 25°C | | 5 | | µs |
| | | 0.01% | | 25°C | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD} = 1$, | $R_L = 10\ k\Omega$ | 25°C | | 40 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L = 10\ k\Omega$, | $C_L = 100$ pF | 25°C | | 60° | | |
| | | $R_L = 600\ \Omega$, | $C_L = 100$ pF | 25°C | | 70° | | |

† Full range is – 55°C to 125°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 20$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2062M | $V_{IC} = 0$, | $R_S = 50\ \Omega$ | 25°C | | 0.9 | 4 | mV |
| | | | | | Full range | | | 6 | |
| | | TLE2062AM | | | 25°C | | 0.8 | 2.6 | |
| | | | | | Full range | | | 4.6 | |
| | | TLE2062BM | | | 25°C | | 0.5 | 1.7 | |
| | | | | | Full range | | | 3.7 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | | Full range | | 6 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | | 25°C | | 0.04 | | µV/mo |
| $I_{IO}$ | Input offset current | | | | 25°C | | 3 | | pA |
| | | | | | Full range | | | 20 | nA |
| $I_{IB}$ | Input bias current | | | | 25°C | | 5 | | pA |
| | | | | | Full range | | | 40 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | | 25°C | − 15<br>to<br>16.5 | − 17<br>to<br>21 | | V |
| | | | | | Full range | − 15<br>to<br>16.5 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | | 25°C | 18 | 18.7 | | V |
| | | | | | Full range | 17.5 | | | |
| | | | $R_L = 600\ \Omega$ | | 25°C | 15 | 18.1 | | |
| | | | | | Full range | 12 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | | 25°C | − 18 | − 18.7 | | V |
| | | | | | Full range | − 17.5 | | | |
| | | | $R_L = 600\ \Omega$ | | 25°C | − 15 | − 18 | | |
| | | | | | Full range | − 12 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 15$ V, | $R_L = 10\ k\Omega$ | 25°C | 30 | 280 | | V/mV |
| | | | | | Full range | 20 | | | |
| | | | $V_O = 0$ to 10 V, | $R_L = 600\ \Omega$ | 25°C | 25 | 80 | | |
| | | | | | Full range | 10 | | | |
| | | | $V_O = 0$ to − 10 V, | $R_L = 600\ \Omega$ | 25°C | 3 | 20 | | |
| | | | | | Full range | 1 | | | |
| $r_i$ | Input resistance | | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | | 25°C | | 560 | | Ω |
| CMRR | Common-mode rejection ratio | | $R_S = 50\ \Omega$,<br>$V_{IC} = V_{ICR}$ min | | 25°C | 75 | 91 | | dB |
| | | | | | Full range | 65 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to ± 20 V,<br>$R_S = 50\ \Omega$ | | 25°C | 75 | 93 | | dB |
| | | | | | Full range | 65 | | | |
| $I_{CC}$ | Supply current (two amplifiers) | | $V_O = 0$, | No load | 25°C | | 660 | 730 | µA |
| | | | | | Full range | | | 770 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range (two amplifiers) | | | | Full range | | 106 | | µA |

†Full range is – 55°C to 125°C.

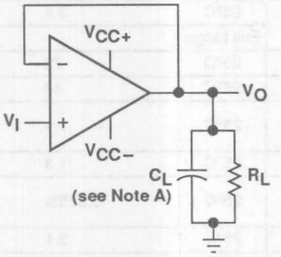
NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 20$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L = 10\ k\Omega$, | $C_L = 100$ pF | 25°C | | 3.4 | | V/μs |
| | | | | Full range | | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S = 100\ \Omega$ | 25°C | | 75 | | nV/√Hz |
| | | f = 1 kHz, | $R_S = 100\ \Omega$ | 25°C | | 40 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | 25°C | | 1.1 | | μV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | 25°C | | 1.3 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD} = 2$,<br>$V_{O(PP)} = 2$ V, | f = 10 kHz,<br>$R_L = 10\ k\Omega$ | 25°C | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L = 10\ k\Omega$, | $C_L = 100$ pF | 25°C | | 2.1 | | MHz |
| | | $R_L = 600\ \Omega$, | $C_L = 100$ pF | 25°C | | 1.6 | | |
| | Settling time | 0.1% | | 25°C | | 5 | | μs |
| | | 0.01% | | 25°C | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD} = 1$, | $R_L = 10\ k\Omega$ | 25°C | | 28 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L = 10\ k\Omega$, | $C_L = 100$ pF | 25°C | | 60° | | |
| | | $R_L = 600\ \Omega$, | $C_L = 100$ pF | 25°C | | 70° | | |

† Full range is – 55°C to 125°C.

## PARAMETER MEASUREMENT INFORMATION



NOTE A: $C_L$ includes fixture capacitance.

**Figure 1. Slew Rate Test Circuit**

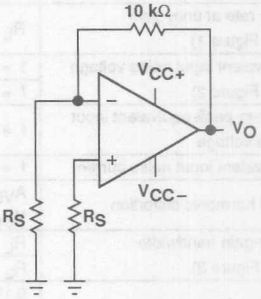
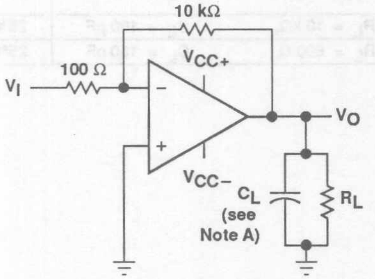


**Figure 2. Noise Voltage Test Circuit**



NOTE A: $C_L$ includes fixture capacitance.

**Figure 3. Unity-Gain Bandwidth and Phase Margin Test Circuit**

### typical values

Typical values as presented in this data sheet represent the median (50% point) of device parametric performance.

### input bias and offset current

At the picoamp bias current level typical of the TLE2062, TLE2062A, and TLE2062B, accurate measurement of the bias current becomes difficult. Not only does this measurement require a picoammeter, but test socket leakages can easily exceed the actual device bias currents. To accurately measure these small currents, Texas Instruments uses a two-step process. The socket leakage is measured using picoammeters with bias voltages applied but with no device in the socket. The device is then inserted into the socket and a second test that measures both the socket leakage and the device input bias current is performed. The two measurements are then subtracted algebraically to determine the bias current of the device.

## TYPICAL CHARACTERISTICS

### table of graphs

| | | | FIGURE |
|---|---|---|---|
| $V_{IO}$ | Input offset voltage | Distribution | 4 |
| $I_{IB}$ | Input bias current | vs Common-mode voltage | 5 |
| | | vs Temperature | 6 |
| $I_{IO}$ | Input offset current | vs Temperature | 6 |
| $V_{ICR}$ | Common-mode input voltage range | vs Temperature | 7 |
| $V_{OM}$ | Maximum peak output voltage swing | vs Output current | 8, 9 |
| | | vs Supply voltage | 10, 11, 12 |
| $V_{O(PP)}$ | Maximum peak-to-peak output voltage | vs Frequency | 13, 14, 15 |
| $A_{VD}$ | Differential voltage amplification | vs Frequency | 16 |
| | | vs Temperature | 17 |
| $I_{OS}$ | Short-circuit output current | vs Time | 18 |
| | | vs Temperature | 19 |
| $z_o$ | Output impedance | vs Frequency | 20 |
| CMRR | Common-mode rejection ratio | vs Frequency | 21 |
| $I_{CC}$ | Supply current | vs Supply voltage | 22 |
| | | vs Temperature | 23 |
| | Pulse response | Small-signal | 24, 25 |
| | | Large-signal | 26, 27 |
| $V_n$ | Noise voltage (referred to input) | 0.1 to 10 Hz | 28 |
| | Equivalent input noise voltage | vs Frequency | 29 |
| THD | Total harmonic distortion | vs Frequency | 30, 31 |
| $B_1$ | Unity-gain bandwidth | vs Supply voltage | 32 |
| | | vs Temperature | 33 |
| $\phi_m$ | Phase margin | vs Supply voltage | 34 |
| | | vs Load capacitance | 35 |
| | | vs Temperature | 36 |
| | Phase shift | vs Frequency | 16 |

## TYPICAL CHARACTERISTICS†

TLE2062
DISTRIBUTION OF
INPUT OFFSET VOLTAGE

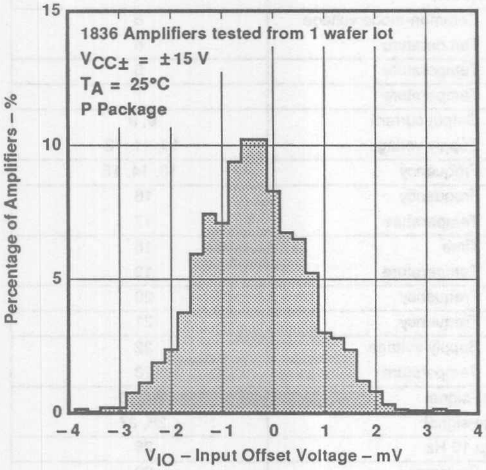


Figure 4

INPUT BIAS CURRENT
vs
COMMON-MODE INPUT VOLTAGE

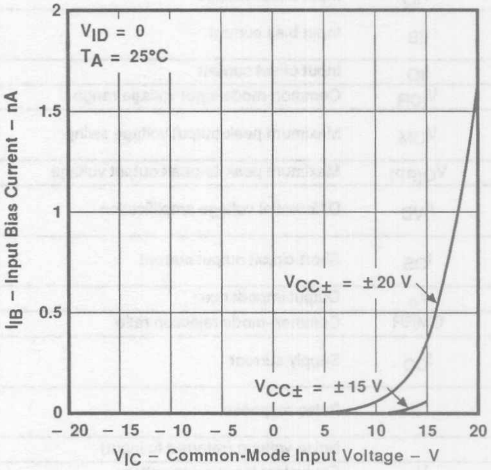


Figure 5

INPUT BIAS CURRENT
and INPUT OFFSET CURRENT
vs
FREE-AIR TEMPERATURE

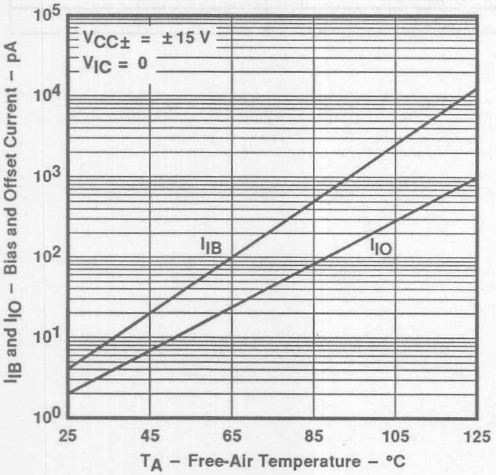


Figure 6

COMMON-MODE INPUT VOLTAGE RANGE
vs
FREE-AIR TEMPERATURE

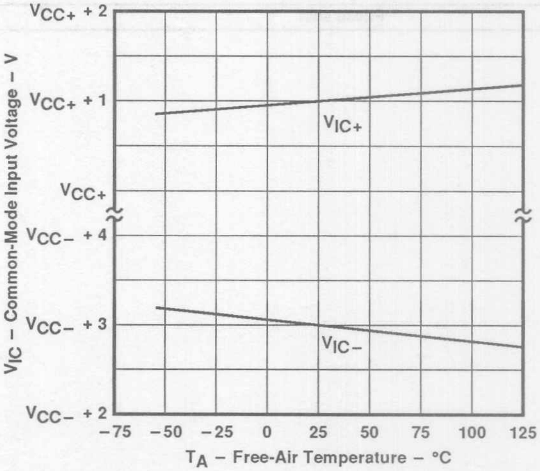


Figure 7

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†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS

MAXIMUM POSITIVE PEAK OUTPUT VOLTAGE vs OUTPUT CURRENT

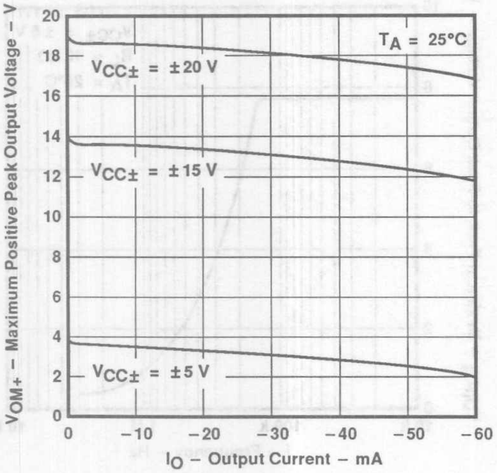

Figure 8

MAXIMUM NEGATIVE PEAK OUTPUT VOLTAGE vs OUTPUT CURRENT

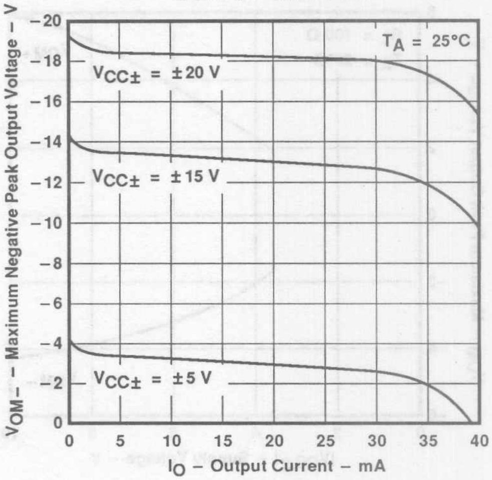

Figure 9

MAXIMUM PEAK OUTPUT VOLTAGE vs SUPPLY VOLTAGE

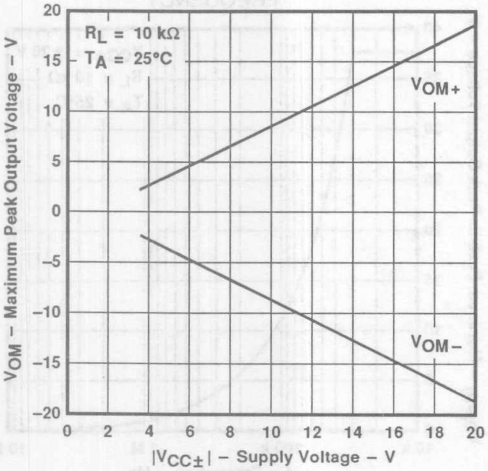

Figure 10

MAXIMUM PEAK OUTPUT VOLTAGE vs SUPPLY VOLTAGE

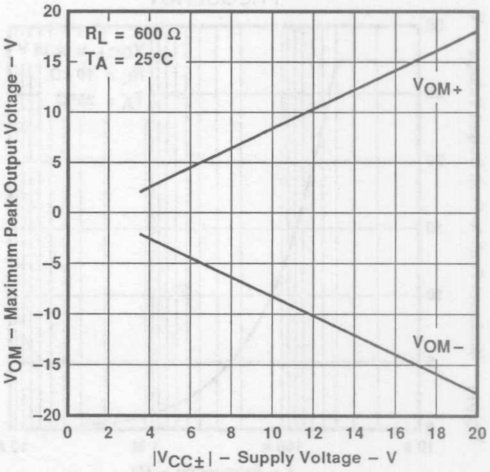

Figure 11

## TYPICAL CHARACTERISTICS

MAXIMUM PEAK OUTPUT VOLTAGE
vs
SUPPLY VOLTAGE

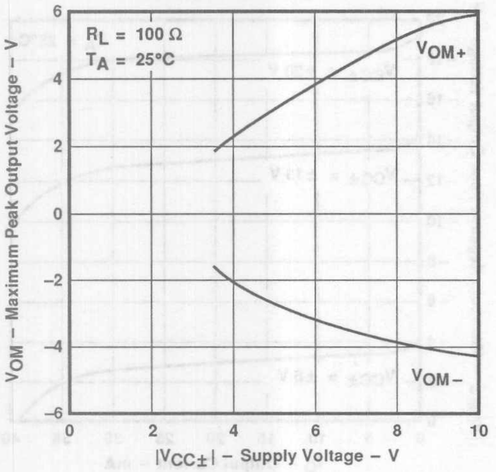

Figure 12

MAXIMUM PEAK-TO-PEAK
OUTPUT VOLTAGE
vs
FREQUENCY

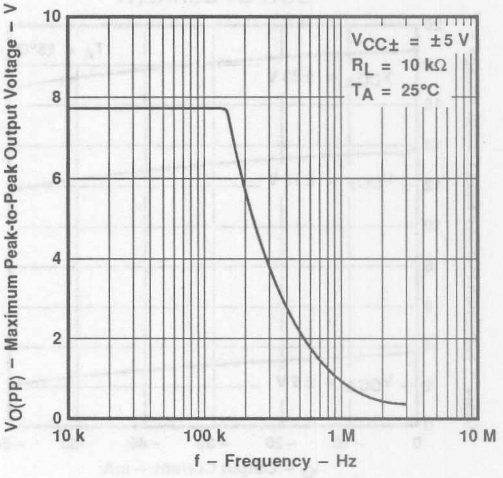

Figure 13

MAXIMUM PEAK-TO-PEAK
OUTPUT VOLTAGE
vs
FREQUENCY

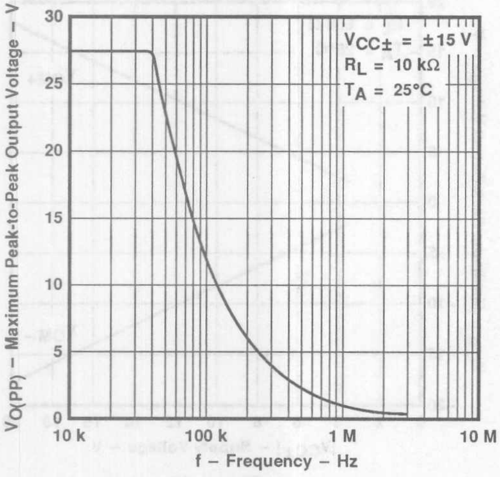

Figure 14

MAXIMUM PEAK-TO-PEAK
OUTPUT VOLTAGE
vs
FREQUENCY

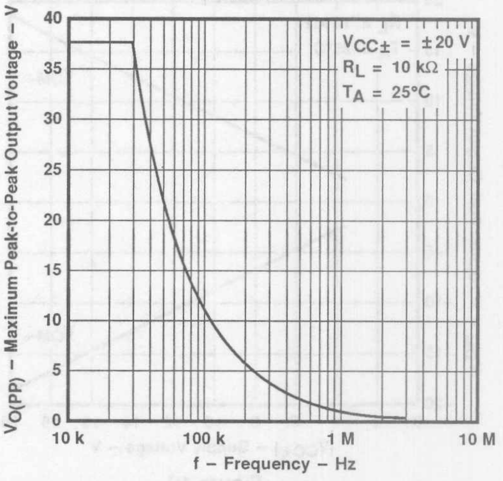

Figure 15

## TYPICAL CHARACTERISTICS†

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION and PHASE SHIFT
vs
FREQUENCY

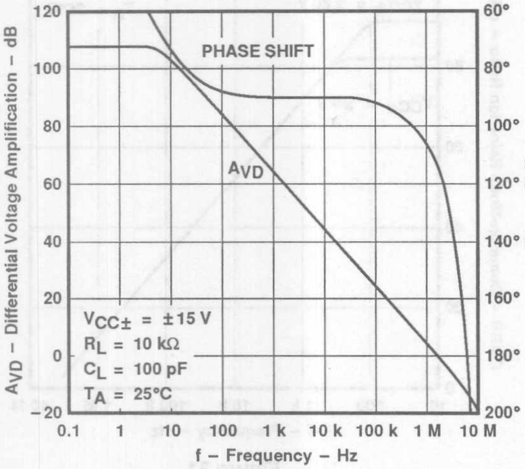

Figure 16

LARGE-SIGNAL VOLTAGE AMPLIFICATION
vs
FREE-AIR TEMPERATURE

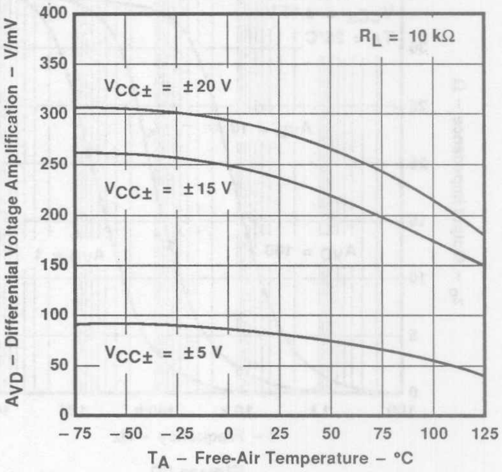

Figure 17

SHORT-CIRCUIT OUTPUT CURRENT
vs
ELAPSED TIME

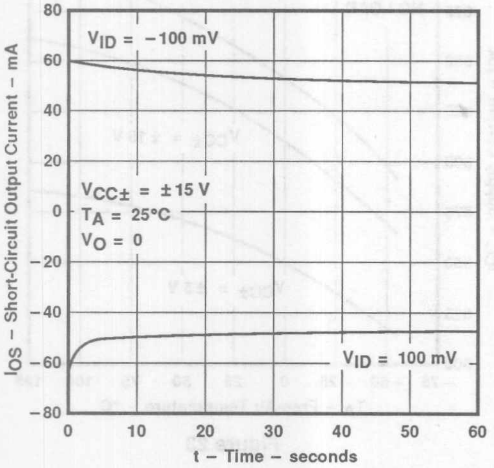

Figure 18

SHORT-CIRCUIT OUTPUT CURRENT
vs
FREE-AIR TEMPERATURE

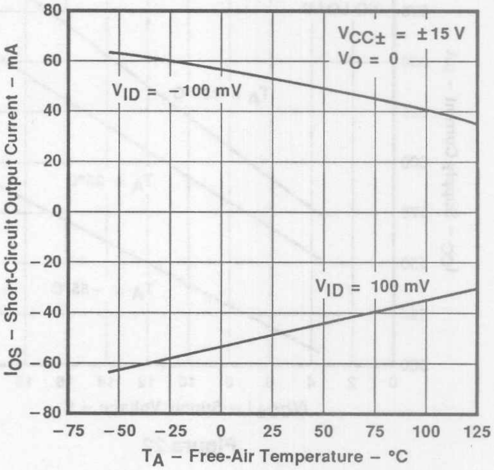

Figure 19

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† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS[†]

OUTPUT IMPEDANCE
vs
FREQUENCY

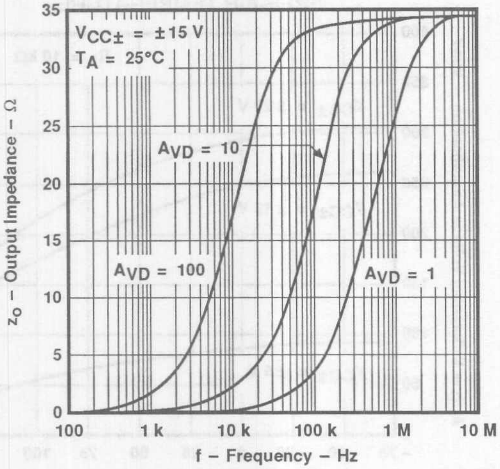

Figure 20

COMMON-MODE REJECTION RATIO
vs
FREQUENCY

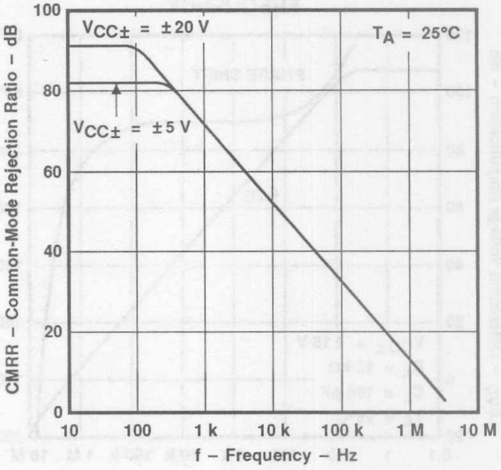

Figure 21

SUPPLY CURRENT
vs
SUPPLY VOLTAGE

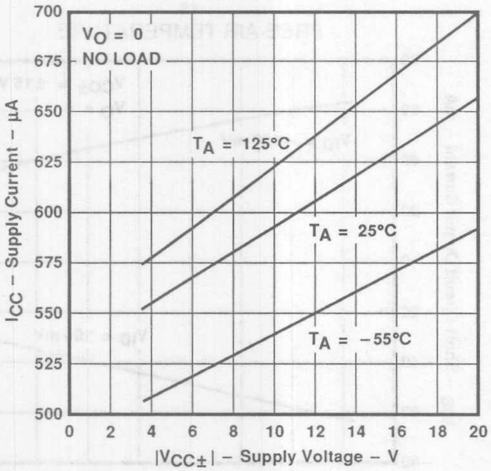

Figure 22

SUPPLY CURRENT
vs
FREE-AIR TEMPERATURE

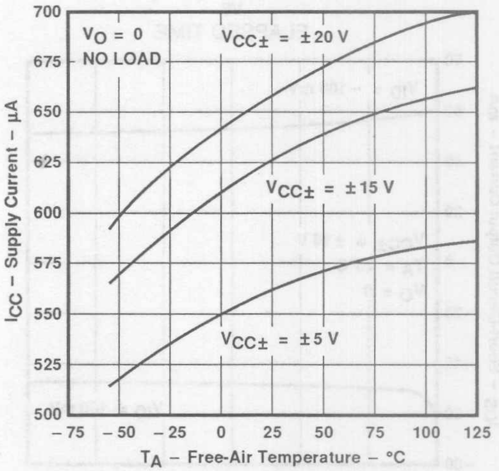

Figure 23

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[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS

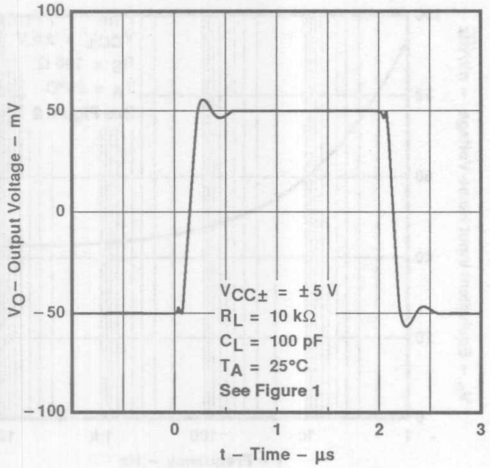
VOLTAGE-FOLLOWER
SMALL-SIGNAL
PULSE RESPONSE

Figure 24

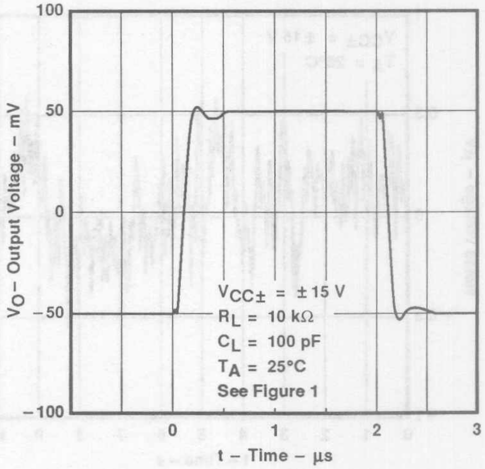
VOLTAGE-FOLLOWER
SMALL-SIGNAL
PULSE RESPONSE

Figure 25

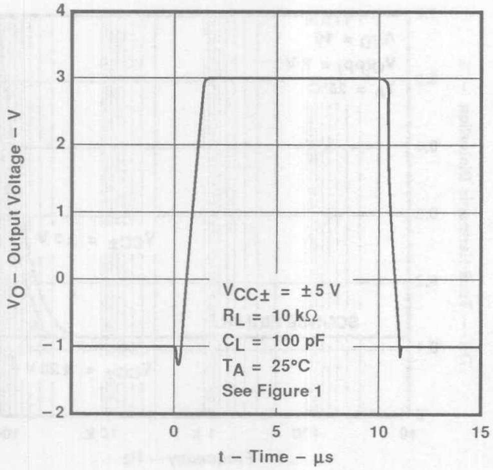
VOLTAGE-FOLLOWER
LARGE-SIGNAL
PULSE RESPONSE

Figure 26

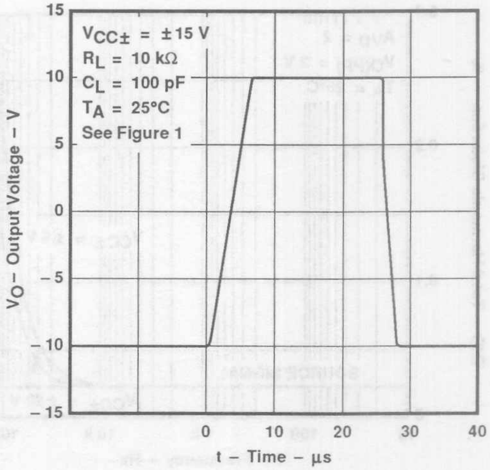
VOLTAGE-FOLLOWER
LARGE-SIGNAL
PULSE RESPONSE

Figure 27

## TYPICAL CHARACTERISTICS

NOISE VOLTAGE
(REFERRED TO INPUT)
0.1 TO 10 Hz

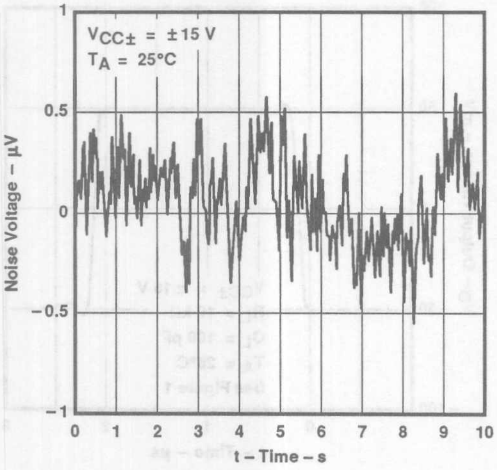

Figure 28

EQUIVALENT INPUT NOISE VOLTAGE
vs
FREQUENCY

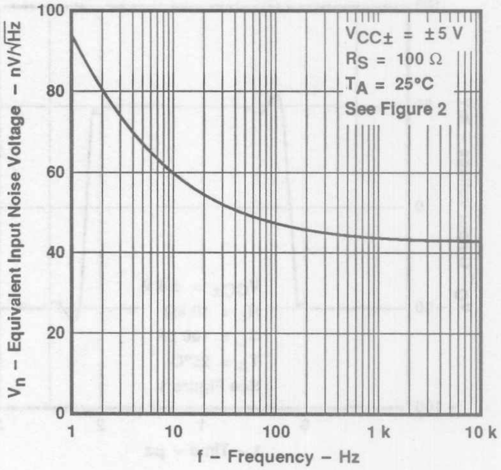

Figure 29

TOTAL HARMONIC DISTORTION
vs
FREQUENCY

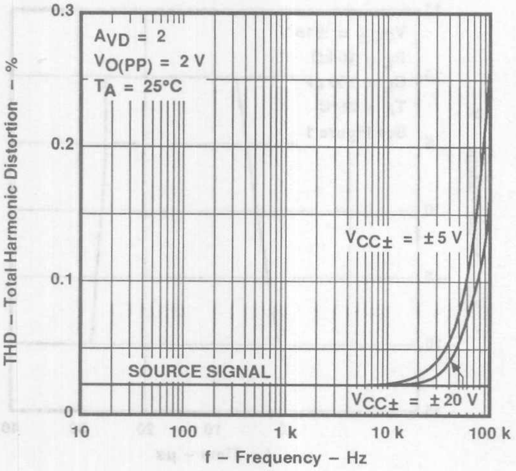

Figure 30

TOTAL HARMONIC DISTORTION
vs
FREQUENCY

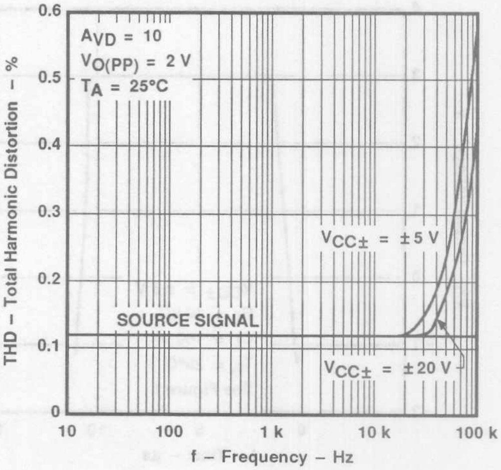

Figure 31

## TYPICAL CHARACTERISTICS[†]

UNITY-GAIN BANDWIDTH
vs
SUPPLY VOLTAGE

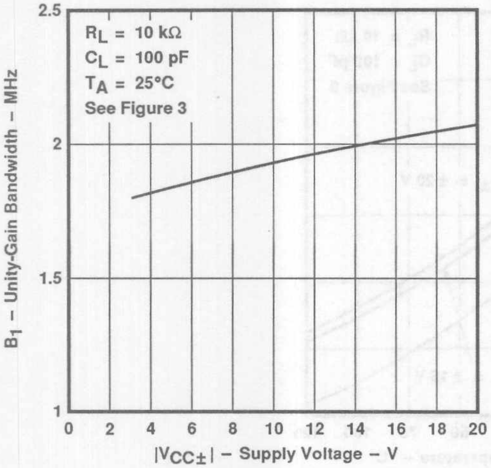

Figure 32

UNITY-GAIN BANDWIDTH
vs
FREE-AIR TEMPERATURE

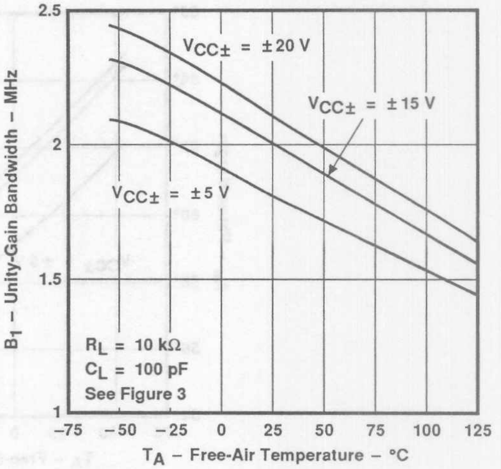

Figure 33

PHASE MARGIN
vs
SUPPLY VOLTAGE

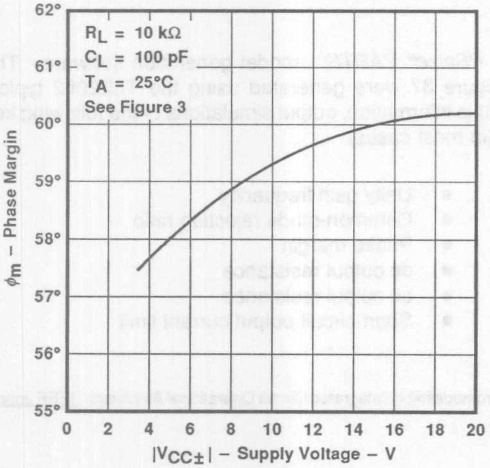

Figure 34

PHASE MARGIN
vs
LOAD CAPACITANCE

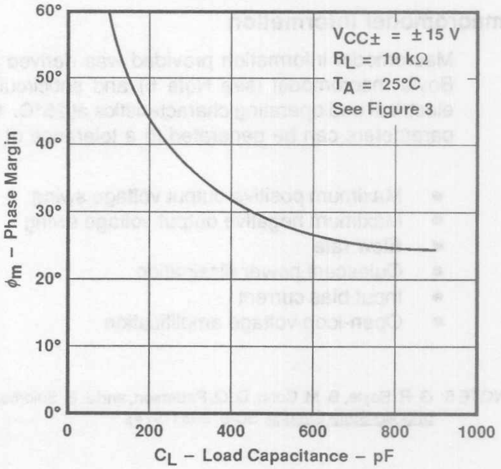

Figure 35

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[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS[†]

PHASE MARGIN
vs
FREE-AIR TEMPERATURE

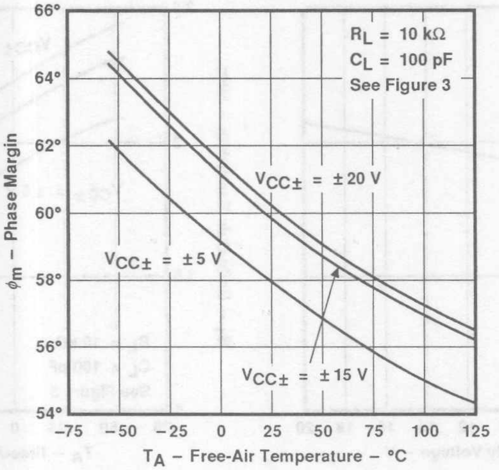

Figure 36

---

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## APPLICATION INFORMATION

### macromodel information

Macromodel information provided was derived using *PSpice*® *PARTS*™ model generation software. The Boyle macromodel (see Note 5) and subcircuit in Figure 37 were generated using the TLE2062 typical electrical and operating characteristics at 25°C. Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

- Maximum positive output voltage swing
- Maximum negative output voltage swing
- Slew rate
- Quiescent power dissipation
- Input bias current
- Open-loop voltage amplification
- Unity gain frequency
- Common-mode rejection ratio
- Phase margin
- dc output resistance
- ac output resistance
- Short-circuit output current limit

NOTE 5: G. R. Boyle, B. M. Cohn, D. O. Pederson, and J. E. Solomon, "Macromodeling of Integrated Circuit Operational Amplifiers", IEEE Journal of Solid-State Circuits, SC-9, 353 (1974).

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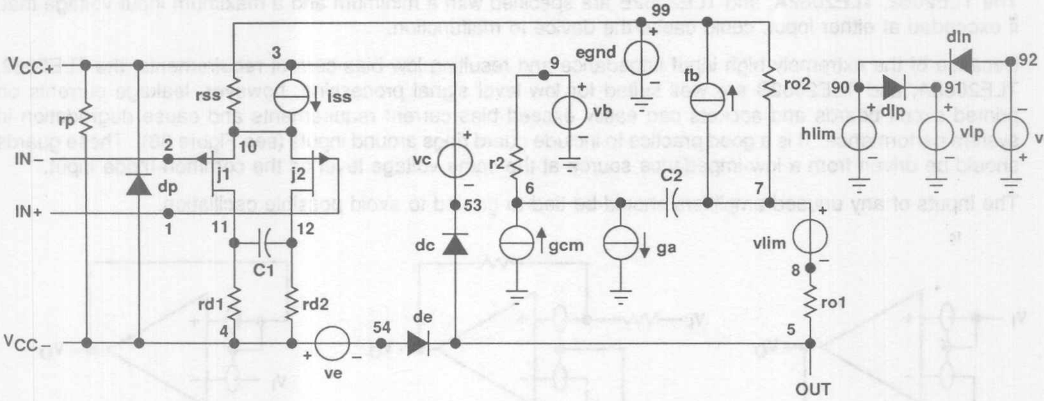
*PSpice* is a registered trademark of MicroSim Corporation.

**Macromodels, simulation models, or other models provided by TI, directly or indirectly, are not warranted by TI as fully representing all of the specifications and operating characteristics of the semiconductor product to which the model relates.**

## APPLICATION INFORMATION

### macromodel information (continued)



```
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  c1   11 12 1.457E-12
  c2    6  7 15.00E-12
  dc    5 53 dx
  de   54  5 dx
  dlp  90 91 dx
  dln  92 90 dx
  dp    4  3 dx
  egnd 99  0 poly(2) (3,0) (4,0) 0 .5 .5
  fb    7 99 poly(5) vb vc ve vlp vln 0 4.357E6 -4E6 4E6 4E6 -4E6
  ga    6  0 11 12 188.5E-6
  gcm   0  6 10 99 3.352E-9
  iss   3 10 dc 51.00E-6
  hlim 90  0 vlim 1K
  j1   11  2 10 jx
  j2   12  1 10 jx
  r2    6  9 100.0E3
  rd1   4 11 5.305E3
  rd2   4 12 5.305E3
  ro1   8  5 280
  ro2   7 99 280
  rp    3  4 113.2E3
  rss  10 99 3.922E6
  vb    9  0 dc 0
  vc    3 53 dc 2
  ve   54  4 dc 2
  vlim  7  8 dc 0
  vlp  91  0 dc 50
  vln   0 92 dc 50
.model dx D(Is=800.0E-18)
.model jx PJF(Is=2.000E-12 Beta=423E-6 Vto=-1)
.ends
```

Figure 37. Boyle Macromodel and Subcircuit

## APPLICATION INFORMATION

### input characteristics

The TLE2062, TLE2062A, and TLE2062B are specified with a minimum and a maximum input voltage that, if exceeded at either input, could cause the device to malfunction.

Because of the extremely high input impedance and resulting low bias current requirements, the TLE2062, TLE2062A, and TLE2062B are well suited for low-level signal processing; however, leakage currents on printed circuit boards and sockets can easily exceed bias current requirements and cause degradation in system performance. It is a good practice to include guard rings around inputs (see Figure 38). These guards should be driven from a low-impedance source at the same voltage level as the common-mode input.

The inputs of any unused amplifiers should be tied to ground to avoid possible oscillation.

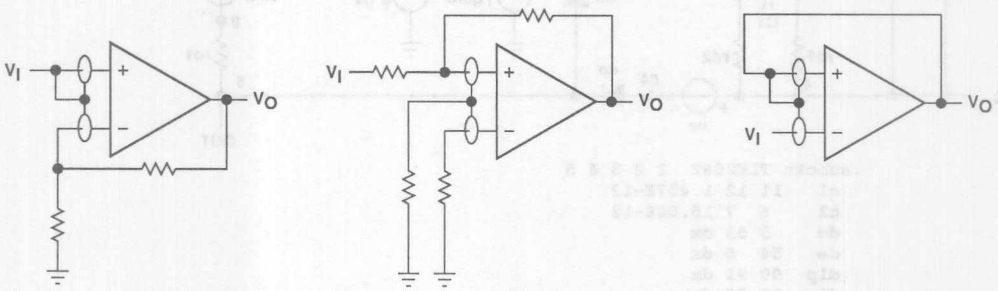


Figure 38. Use of Guard Rings

# TLE2064, TLE2064A, TLE2064B
# EXCALIBUR JFET-INPUT HIGH-OUTPUT-DRIVE μPOWER QUAD OPERATIONAL AMPLIFIERS

D3367, NOVEMBER 1989 – REVISED FEBRUARY 1991

## available features

- Excellent Output Drive Capability . . .
  $V_O$ = ± 2.5 V Min at $R_L$ = 100 Ω,
  $V_{CC\pm}$ = ± 5 V
  $V_O$ = ± 12.5 V Min at $R_L$ = 600 Ω,
  $V_{CC\pm}$ = ± 15 V
- Low Supply Current . . . 280 μA Typ Per Amplifier
- High Unity-Gain Bandwidth . . . 2.1 MHz Typ
- High Slew Rate . . . 3.4 V/μs Typ
- Macromodels Included
- Wide Operating Supply Voltage Range . . . $V_{CC\pm}$ = ± 3.5 V to ± 20 V
- High Open-Loop Gain . . . 280 V/mV Typ
- Low Offset Voltage . . . 2 mV Max
- Low Offset Voltage Drift With Time . . . 0.04 μV/mo Typ
- Low Input Bias Current . . . 5 pA Typ

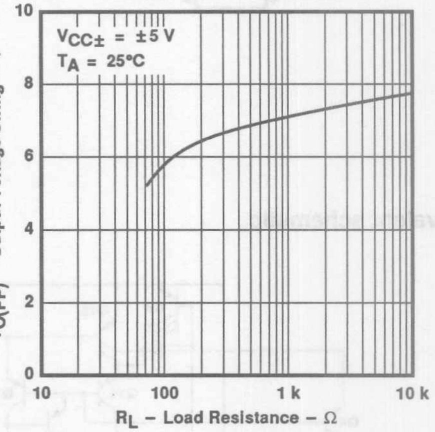
## description

The TLE2064, TLE2064A, and TLE2064B are JFET-input, low-power, precision operational amplifiers manufactured using Texas Instruments Excalibur process. These devices combine outstanding output drive capability with low-power consumption, excellent dc precision, and wide bandwidth.

In addition to maintaining the traditional JFET advantages of fast slew rates and low input bias and offset currents, the Excalibur process offers outstanding parametric stability over time and temperature. This results in a "precision" device remaining precise even with changes in temperature and over years of use.

The TLE2064, TLE2064A, and TLE2064B are ideal choices for any application requiring excellent dc precision, high output drive, wide bandwidth, and low power consumption.

MAXIMUM PEAK-TO-PEAK
OUTPUT VOLTAGE SWING
vs
LOAD RESISTANCE



### AVAILABLE OPTIONS

| $T_A$ | $V_{IO}$ max AT 25°C | PACKAGE | | | |
|---|---|---|---|---|---|
| | | SMALL-OUTLINE (D) | CHIP CARRIER (FK) | CERAMIC DIP (J) | PLASTIC DIP (N) |
| 0°C | 2 mV | — | — | — | TLE2064BCN |
| to | 4 mV | TLE2064ACD | — | — | TLE2064ACN |
| 70°C | 6 mV | TLE2064CD | — | — | TLE2064CN |
| – 40°C | 2 mV | — | — | — | TLE2064BIN |
| to | 4 mV | TLE2064AID | — | — | TLE2064AIN |
| 85°C | 6 mV | TLE2064ID | — | — | TLE2064IN |
| – 55°C | 2 mV | — | — | TLE2064BMJ | TLE2064BMN |
| to | 4 mV | TLE2064AMD | TLE2064AMFK | TLE2064AMJ | TLE2064AMN |
| 125°C | 6 mV | TLE2064MD | TLE2064MFK | TLE2064MJ | TLE2064MN |

D packages are available taped and reeled. Add "R" suffix to device type, (e.g., TLE2064ACDR).

PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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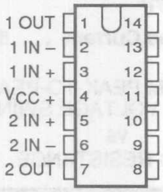
## description (continued)

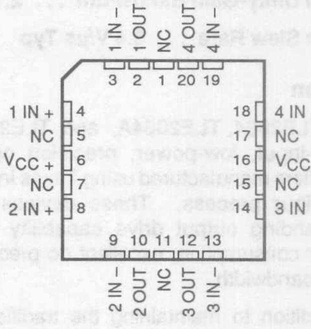
A variety of available package options includes small-outline and chip-carrier versions for high-density system applications.

The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from −40°C to 85°C. The M-suffix devices are characterized for operation over the full military temperature range of −55°C to 125°C.

**D, J, OR N PACKAGE**
**(TOP VIEW)**

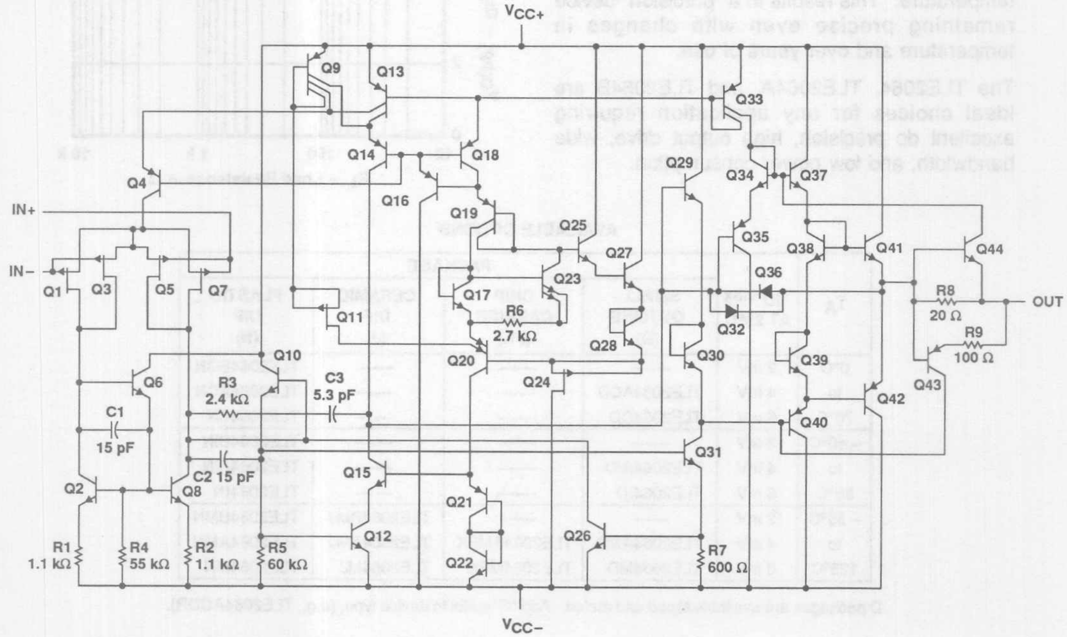


**FK PACKAGE**
**(TOP VIEW)**



NC – No internal connection

## equivalent schematic



All component values are nominal.

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|---|
| Supply voltage, $V_{CC+}$ (see Note 1) | 22 V |
| Supply voltage, $V_{CC-}$ | –22 V |
| Differential input voltage (see Note 2) | ±44 V |
| Input voltage range, $V_I$ (any input) | $V_{CC\pm}$ |
| Input current, $I_I$ (each input) | ±1 mA |
| Output current, $I_O$ (each output) | ±80 mA |
| Total current into $V_{CC+}$ terminal | 80 mA |
| Total current out of $V_{CC-}$ terminal | 80 mA |
| Duration of short-circuit current at (or below) 25°C (see Note 3) | unlimited |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range, $T_A$: C-suffix | 0°C to 70°C |
| I-suffix | –40°C to 85°C |
| M-suffix | –55°C to 125°C |
| Storage temperature range | –65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package | 300°C |

NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between $V_{CC+}$ and $V_{CC-}$.
2. Differential voltages are at the noninverting input with respect to the inverting input.
3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \le 25°C$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25°C$ | $T_A = 70°C$ POWER RATING | $T_A = 85°C$ POWER RATING | $T_A = 125°C$ POWER RATING |
|---|---|---|---|---|---|
| D | 950 mW | 7.6 mW/°C | 608 mW | 494 mW | 190 mW |
| FK | 1375 mW | 11.0 mW/°C | 880 mW | 715 mW | 275 mW |
| J | 1375 mW | 11.0 mW/°C | 880 mW | 715 mW | 275 mW |
| N | 1575 mW | 12.6 mW/°C | 1008 mW | 819 mW | 315 mW |

## recommended operating conditions

| | | C-SUFFIX | | I-SUFFIX | | M-SUFFIX | | UNIT |
|---|---|---|---|---|---|---|---|---|
| | | MIN | MAX | MIN | MAX | MIN | MAX | |
| Supply voltage, $V_{CC\pm}$ | | ± 3.5 | ± 20 | ± 3.5 | ± 20 | ± 3.5 | ± 20 | V |
| Common-mode input voltage, $V_{IC}$ | $V_{CC\pm} = \pm 5$ V | – 1.6 | 4 | – 1.6 | 4 | – 1.6 | 4 | V |
| | $V_{CC\pm} = \pm 15$ V | – 11 | 13 | – 11 | 13 | – 11 | 13 | |
| | $V_{CC\pm} = \pm 20$ V | – 15 | 16.5 | – 15 | 16.5 | – 15 | 16.5 | |
| Operating free-air temperature, $T_A$ | | 0 | 70 | – 40 | 85 | – 55 | 125 | °C |

## electrical characteristics at specified free-air temperature, $V_{CC\pm}$ = ±5 V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2064C | $V_{IC}$ = 0, $R_S$ = 50 Ω | 25°C | | 1.2 | 7 | mV |
| | | | | Full range | | | 7.9 | |
| | | TLE2064AC | | 25°C | | 1.2 | 6 | |
| | | | | Full range | | | 6.9 | |
| | | TLE2064BC | | 25°C | | 0.8 | 3.5 | |
| | | | | Full range | | | 4.4 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | µV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 1 | | pA |
| | | | | Full range | | | 0.8 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 3 | | pA |
| | | | | Full range | | | 2 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | −1.6<br>to<br>4 | −2<br>to<br>6 | | V |
| | | | | Full range | −1.6<br>to<br>4 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L$ = 10 kΩ | 25°C | 3.5 | 3.7 | | V |
| | | | | Full range | 3.3 | | | |
| | | | $R_L$ = 100 Ω | 25°C | 2.5 | 3.1 | | |
| | | | | Full range | 2 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L$ = 10 kΩ | 25°C | −3.7 | −3.9 | | V |
| | | | | Full range | −3.3 | | | |
| | | | $R_L$ = 100 Ω | 25°C | −2.5 | −2.7 | | |
| | | | | Full range | −2 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O$ = ±2.8 V, $R_L$ = 10 kΩ | 25°C | 15 | 80 | | V/mV |
| | | | | Full range | 2 | | | |
| | | | $V_O$ = 0 to 2 V, $R_L$ = 100 Ω | 25°C | 0.75 | 45 | | |
| | | | | Full range | 0.5 | | | |
| | | | $V_O$ = 0 to −2 V, $R_L$ = 100 Ω | 25°C | 0.5 | 3 | | |
| | | | | Full range | 0.15 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O$ = 0 | 25°C | | 560 | | Ω |
| CMRR | Common-mode rejection ratio | | $V_{IC}$ = $V_{ICR}$ min, $R_S$ = 50 Ω | 25°C | 65 | 82 | | dB |
| | | | | Full range | 65 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm}$ = ±5 V to ±20 V, $R_S$ = 50 Ω | 25°C | 75 | 93 | | dB |
| | | | | Full range | 75 | | | |
| $I_{CC}$ | Supply current (four amplifiers) | | $V_O$ = 0, No load | 25°C | | 1.12 | 1.3 | mA |
| | | | | Full range | | | 1.3 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range (four amplifiers) | | | Full range | | 52 | | µA |
| $V_{o1}/V_{o2}$ | Crosstalk attenuation | | $A_{VD}$ = 1000, f = 1 kHz | 25°C | | 120 | | dB |

†Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A$ = 150°C extrapolated to $T_A$ = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L = 10\ \text{k}\Omega$, | $C_L = 100$ pF | 25°C | 2.2 | 3.4 | | V/µs |
| | | | | Full range | 2.1 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S = 100\ \Omega$ | 25°C | | 59 | 100 | nV/√Hz |
| | | f = 1 kHz, | $R_S = 100\ \Omega$ | | | 43 | 60 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | 25°C | | 1.1 | | µV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | 25°C | | 1 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD} = 2$,<br>$V_{O(PP)} = 2$ V, | f = 10 kHz,<br>$R_L = 10\ \text{k}\Omega$ | 25°C | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L = 10\ \text{k}\Omega$, | $C_L = 100$ pF | 25°C | | 1.8 | | MHz |
| | | $R_L = 100\ \Omega$, | $C_L = 100$ pF | | | 1.3 | | |
| | Settling time | $\varepsilon = 0.1\%$ | | 25°C | | 5 | | µs |
| | | $\varepsilon = 0.01\%$ | | | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD} = 1$, | $R_L = 10\ \text{k}\Omega$ | 25°C | | 140 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L = 10\ \text{k}\Omega$, | $C_L = 100$ pF | 25°C | | 58° | | |
| | | $R_L = 100\ \Omega$, | $C_L = 100$ pF | | | 75° | | |

†Full range is 0°C to 70°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2064C | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 0.9 | 6 | mV |
| | | | | Full range | | | 6.9 | |
| | | TLE2064AC | | 25°C | | 0.9 | 4 | |
| | | | | Full range | | | 4.9 | |
| | | TLE2064BC | | 25°C | | 0.7 | 2 | |
| | | | | Full range | | | 4 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | µV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 2 | | pA |
| | | | | Full range | | | 1 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 4 | | pA |
| | | | | Full range | | | 3 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | − 11<br>to<br>13 | − 12<br>to<br>16 | | V |
| | | | | Full range | − 11<br>to<br>13 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 13.2 | 13.7 | | V |
| | | | | Full range | 13 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | 12.5 | 13.2 | | |
| | | | | Full range | 12 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | − 13.2 | − 13.7 | | V |
| | | | | Full range | − 13 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | − 12.5 | − 13 | | |
| | | | | Full range | − 12 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 10$ V, $R_L = 10\ k\Omega$ | 25°C | 30 | 230 | | V/mV |
| | | | | Full range | 20 | | | |
| | | | $V_O = 0$ to 8 V, $R_L = 600\ \Omega$ | 25°C | 25 | 100 | | |
| | | | | Full range | 10 | | | |
| | | | $V_O = 0$ to $-8$ V, $R_L = 600\ \Omega$ | 25°C | 3 | 25 | | |
| | | | | Full range | 1 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | 25°C | | 560 | | Ω |
| CMRR | Common-mode rejection ratio | | $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 25°C | 72 | 90 | | dB |
| | | | | Full range | 70 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to $\pm 15$ V, $R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | | | Full range | 75 | | | |
| $I_{CC}$ | Supply current (four amplifiers) | | $V_O = 0$, No load | 25°C | | 1.25 | 1.4 | mA |
| | | | | Full range | | | 1.5 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range (four amplifiers) | | | Full range | | 72 | | µA |
| $V_{o1}/V_{o2}$ | Crosstalk attenuation | | $A_{VD} = 1000$, f = 1 kHz | 25°C | | 120 | | dB |

† Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150$°C extrapolated to $T_A = 25$°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| | PARAMETER | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | 2.6 | 3.4 | | V/μs |
| | | | | Full range | 2.5 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S$ = 100 Ω | 25°C | | 70 | 100 | nV/√Hz |
| | | f = 1 kHz, | $R_S$ = 100 Ω | | | 40 | 60 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | 25°C | | 1.1 | | μV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | 25°C | | 1.1 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD}$ = 2,<br>$V_{O(PP)}$ = 2 V, | f = 10 kHz,<br>$R_L$ = 10 kΩ | 25°C | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 2 | | MHz |
| | | $R_L$ = 600 Ω, | $C_L$ = 100 pF | | | 1.5 | | |
| | Settling time | ε = 0.1% | | 25°C | | 5 | | μs |
| | | ε = 0.01% | | | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD}$ = 1, | $R_L$ = 10 kΩ | 25°C | | 40 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 60° | | |
| | | $R_L$ = 600 Ω, | $C_L$ = 100 pF | | | 70° | | |

† Full range is 0°C to 70°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 20$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2064C | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 1 | 6 | mV |
| | | | | Full range | | | 6.9 | |
| | | TLE2064AC | | 25°C | | 1 | 4.6 | |
| | | | | Full range | | | 5.5 | |
| | | TLE2064BC | | 25°C | | 0.7 | 2.2 | |
| | | | | Full range | | | 3.1 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | μV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | μV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 3 | | pA |
| | | | | Full range | | | 1 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 5 | | pA |
| | | | | Full range | | | 3 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | − 15 to 16.5 | − 17 to 21 | | V |
| | | | | Full range | − 15 to 16.5 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 18.2 | 18.7 | | V |
| | | | | Full range | 18 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | 15 | 18.1 | | |
| | | | | Full range | 12 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | − 18.2 | − 18.7 | | V |
| | | | | Full range | − 18 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | − 15 | − 18 | | |
| | | | | Full range | − 12 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 15$ V, $R_L = 10\ k\Omega$ | 25°C | 30 | 280 | | V/mV |
| | | | | Full range | 20 | | | |
| | | | $V_O = 0$ to 10 V, $R_L = 600\ \Omega$ | 25°C | 25 | 80 | | |
| | | | | Full range | 10 | | | |
| | | | $V_O = 0$ to − 10 V, $R_L = 600\ \Omega$ | 25°C | 3 | 20 | | |
| | | | | Full range | 1 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | 25°C | | 560 | | Ω |
| CMRR | Common-mode rejection ratio | | $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 25°C | 75 | 91 | | dB |
| | | | | Full range | 70 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to $\pm 20$ V, $R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | | | Full range | 70 | | | |
| $I_{CC}$ | Supply current (four amplifiers) | | $V_O = 0$, No load | 25°C | | 1.32 | 1.5 | mA |
| | | | | Full range | | | 1.5 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range (four amplifiers) | | | Full range | | 82 | | μA |
| $V_{o1}/V_{o2}$ | Crosstalk attenuation | | $A_{VD} = 1000$, f = 1 kHz | | | 120 | | dB |

†Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150$°C extrapolated to $T_A = 25$°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 20$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | 2.8 | 3.4 | | V/μs |
| | | | | Full range | 2.5 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S$ = 100 Ω | 25°C | | 75 | 100 | nV/√Hz |
| | | f = 1 kHz, | $R_S$ = 100 Ω | | | 40 | 60 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | 25°C | | 1.1 | | μV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | 25°C | | 1.3 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD}$ = 2,<br>$V_{O(PP)}$ = 2 V, | f = 10 kHz,<br>$R_L$ = 10 kΩ | 25°C | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 2.1 | | MHz |
| | | $R_L$ = 600 Ω, | $C_L$ = 100 pF | | | 1.6 | | |
| | Settling time | ε = 0.1% | | 25°C | | 5 | | μs |
| | | ε = 0.01% | | | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD}$ = 1, | $R_L$ = 10 kΩ | 25°C | | 28 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 60° | | |
| | | $R_L$ = 600 Ω, | $C_L$ = 100 pF | | | 70° | | |

† Full range is 0°C to 70°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 5$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2064I | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 1.2 | 7 | mV |
| | | | | Full range | | | 8.3 | |
| | | TLE2064AI | | 25°C | | 1.2 | 6 | |
| | | | | Full range | | | 7.3 | |
| | | TLE2064BI | | 25°C | | 0.8 | 3.5 | |
| | | | | Full range | | | 4.8 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | µV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 1 | | pA |
| | | | | Full range | | | 2 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 3 | | pA |
| | | | | Full range | | | 4 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | − 1.6<br>to<br>4 | − 2<br>to<br>6 | | V |
| | | | | Full range | − 1.6<br>to<br>4 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 3.5 | 3.7 | | V |
| | | | | Full range | 3.1 | | | |
| | | | $R_L = 100\ \Omega$ | 25°C | 2.5 | 3.1 | | |
| | | | | Full range | 2 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | − 3.7 | − 3.9 | | V |
| | | | | Full range | − 3.1 | | | |
| | | | $R_L = 100\ \Omega$ | 25°C | − 2.5 | − 2.7 | | |
| | | | | Full range | − 2 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 2.8$ V, $R_L = 10\ k\Omega$ | 25°C | 15 | 80 | | V/mV |
| | | | | Full range | 2 | | | |
| | | | $V_O = 0$ to 2 V, $R_L = 100\ \Omega$ | 25°C | 0.75 | 45 | | |
| | | | | Full range | 0.5 | | | |
| | | | $V_O = 0$ to − 2 V, $R_L = 100\ \Omega$ | 25°C | 0.5 | 3 | | |
| | | | | Full range | 0.15 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | 25°C | | 560 | | Ω |
| CMRR | Common-mode rejection ratio | | $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 25°C | 65 | 82 | | dB |
| | | | | Full range | 65 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to ± 20 V, $R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | | | Full range | 65 | | | |
| $I_{CC}$ | Supply current (four amplifiers) | | $V_O = 0$, No load | 25°C | | 1.12 | 1.3 | mA |
| | | | | Full range | | | 1.3 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range (four amplifiers) | | | Full range | | 108 | | µA |
| $V_{o1}/V_{o2}$ | Crosstalk attenuation | | $A_{VD} = 1000$, $f = 1$ kHz | 25°C | | 120 | | dB |

† Full range is – 40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150$°C extrapolated to $T_A = 25$°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm}$ = ±5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | 2.2 | 3.4 | | V/µs |
| | | | | Full range | 1.7 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S$ = 100 Ω | 25°C | | 59 | 100 | nV/√Hz |
| | | f = 1 kHz, | $R_S$ = 100 Ω | | | 43 | 60 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | 25°C | | 1.1 | | µV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | 25°C | | 1 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD}$ = 2,<br>$V_{O(PP)}$ = 2 V, | f = 10 kHz,<br>$R_L$ = 10 kΩ | 25°C | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 1.8 | | MHz |
| | | $R_L$ = 100 Ω, | $C_L$ = 100 pF | | | 1.3 | | |
| | Settling time | ε = 0.1% | | 25°C | | 5 | | µs |
| | | ε = 0.01% | | | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD}$ = 1, | $R_L$ = 10 kΩ | 25°C | | 140 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 58° | | |
| | | $R_L$ = 100 Ω, | $C_L$ = 100 pF | | | 75° | | |

†Full range is – 40°C to 85°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2064I | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 0.9 | 6 | mV |
| | | | | Full range | | | 7.3 | |
| | | TLE2064AI | | 25°C | | 0.9 | 4 | |
| | | | | Full range | | | 5.3 | |
| | | TLE2064BI | | 25°C | | 0.7 | 2 | |
| | | | | Full range | | | 3.3 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | μV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | μV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 2 | | pA |
| | | | | Full range | | | 3 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 4 | | pA |
| | | | | Full range | | | 5 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | − 11<br>to<br>13 | − 12<br>to<br>16 | | V |
| | | | | Full range | − 11<br>to<br>13 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 13.2 | 13.7 | | V |
| | | | | Full range | 13 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | 12.5 | 13.2 | | |
| | | | | Full range | 12 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | − 13.2 | − 13.7 | | V |
| | | | | Full range | − 13 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | − 12.5 | − 13 | | |
| | | | | Full range | − 12 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 10$ V, $R_L = 10\ k\Omega$ | 25°C | 30 | 230 | | V/mV |
| | | | | Full range | 20 | | | |
| | | | $V_O = 0$ to 8 V, $R_L = 600\ \Omega$ | 25°C | 25 | 100 | | |
| | | | | Full range | 10 | | | |
| | | | $V_O = 0$ to − 8 V, $R_L = 600\ \Omega$ | 25°C | 3 | 25 | | |
| | | | | Full range | 1 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | 25°C | | 560 | | Ω |
| CMRR | Common-mode rejection ratio | | $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 25°C | 72 | 90 | | dB |
| | | | | Full range | 65 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to $\pm 15$ V, $R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | | | Full range | 65 | | | |
| $I_{CC}$ | Supply current (four amplifiers) | | $V_O = 0$, No load | 25°C | | 1.25 | 1.4 | mA |
| | | | | Full range | | | 1.5 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range (four amplifiers) | | | Full range | | 148 | | μA |
| $V_{o1}/V_{o2}$ | Crosstalk attenuation | | $A_{VD} = 1000$, $f = 1$ kHz | 25°C | | 120 | | dB |

†Full range is – 40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150$°C extrapolated to $T_A = 25$°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | 2.6 | 3.4 | | V/µs |
| | | | | Full range | 2.1 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S$ = 100 Ω | 25°C | | 70 | 100 | nV/√Hz |
| | | f = 1 kHz, | $R_S$ = 100 Ω | | | 40 | 60 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | 25°C | | 1.1 | | µV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | 25°C | | 1.1 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD}$ = 2,<br>$V_{O(PP)}$ = 2 V, | f = 10 kHz,<br>$R_L$ = 10 kΩ | 25°C | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 2 | | MHz |
| | | $R_L$ = 600 Ω, | $C_L$ = 100 pF | | | 1.5 | | |
| | Settling time | ε = 0.1% | | 25°C | | 5 | | µs |
| | | ε = 0.01% | | | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD}$ = 1, | $R_L$ = 10 kΩ | 25°C | | 40 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 60° | | |
| | | $R_L$ = 600 Ω, | $C_L$ = 100 pF | | | 70° | | |

† Full range is – 40°C to 85°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 20$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2064I | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 1 | 6 | mV |
| | | | | Full range | | | 7.3 | |
| | | TLE2064AI | | 25°C | | 1 | 4.6 | |
| | | | | Full range | | | 5.9 | |
| | | TLE2064BI | | 25°C | | 0.7 | 2.2 | |
| | | | | Full range | | | 3.5 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | µV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 3 | | pA |
| | | | | Full range | | | 3 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 5 | | pA |
| | | | | Full range | | | 5 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | – 15<br>to<br>16.5 | – 17<br>to<br>21 | | V |
| | | | | Full range | – 15<br>to<br>16.5 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 18.2 | 18.7 | | V |
| | | | | Full range | 18 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | 15 | 18.1 | | |
| | | | | Full range | 12 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | – 18.2 | – 18.7 | | V |
| | | | | Full range | – 18 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | – 15 | – 18 | | |
| | | | | Full range | – 12 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 15$ V, $R_L = 10\ k\Omega$ | 25°C | 30 | 280 | | V/mV |
| | | | | Full range | 20 | | | |
| | | | $V_O = 0$ to 10 V, $R_L = 600\ \Omega$ | 25°C | 25 | 80 | | |
| | | | | Full range | 10 | | | |
| | | | $V_O = 0$ to – 10 V, $R_L = 600\ \Omega$ | 25°C | 3 | 20 | | |
| | | | | Full range | 1 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | 25°C | | 560 | | Ω |
| CMRR | Common-mode rejection ratio | | $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 25°C | 75 | 91 | | dB |
| | | | | Full range | 65 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to $\pm 20$ V, $R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | | | Full range | 65 | | | |
| $I_{CC}$ | Supply current (four amplifiers) | | $V_O = 0$, No load | 25°C | | 1.32 | 1.5 | mA |
| | | | | Full range | | | 1.6 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range (four amplifiers) | | | Full range | | 164 | | µA |
| $V_{o1}/V_{o2}$ | Crosstalk attenuation | | $A_{VD} = 1000$, $f = 1$ kHz | 25°C | | 120 | | dB |

†Full range is – 40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 20$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | 2.8 | 3.4 | | V/μs |
| | | | Full range | 2.1 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, $R_S$ = 100 Ω | 25°C | | 75 | 100 | nV/√Hz |
| | | f = 1 kHz, $R_S$ = 100 Ω | | | 40 | 60 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | 25°C | | 1.1 | | μV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | 25°C | | 1.3 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD}$ = 2, f = 10 kHz,<br>$V_{O(PP)}$ = 2 V, $R_L$ = 10 kΩ | 25°C | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 2.1 | | MHz |
| | | $R_L$ = 600 Ω, $C_L$ = 100 pF | | | 1.6 | | |
| | Settling time | ε = 0.1% | 25°C | | 5 | | μs |
| | | ε = 0.01% | | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD}$ = 1, $R_L$ = 10 kΩ | 25°C | | 28 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 60° | | |
| | | $R_L$ = 600 Ω, $C_L$ = 100 pF | | | 70° | | |

†Full range is – 40°C to 85°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 5$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2064M | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 1.2 | 7 | mV |
| | | | | Full range | | | 9 | |
| | | TLE2064AM | | 25°C | | 1.2 | 6 | |
| | | | | Full range | | | 8 | |
| | | TLE2064BM | | 25°C | | 0.8 | 3.5 | |
| | | | | Full range | | | 5.5 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | μV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | μV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 1 | | pA |
| | | | | Full range | | | 15 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 3 | | pA |
| | | | | Full range | | | 30 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | − 1.6<br>to<br>4 | − 2<br>to<br>6 | | V |
| | | | | Full range | − 1.6<br>to<br>4 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 3.5 | 3.7 | | V |
| | | | | Full range | 3 | | | |
| | | FK and J packages | $R_L = 600\ \Omega$ | 25°C | 2.5 | 3.6 | | |
| | | | | Full range | 2 | | | |
| | | D and N packages | $R_L = 100\ \Omega$ | 25°C | 2.5 | 3.1 | | |
| | | | | Full range | 2 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | − 3.5 | − 3.9 | | V |
| | | | | Full range | − 3 | | | |
| | | FK and J packages | $R_L = 600\ \Omega$ | 25°C | − 2.5 | − 3.5 | | |
| | | | | Full range | − 2 | | | |
| | | D and N packages | $R_L = 100\ \Omega$ | 25°C | − 2.5 | − 2.7 | | |
| | | | | Full range | − 2 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 2.8$ V, $R_L = 10\ k\Omega$ | 25°C | 15 | 80 | | V/mV |
| | | | | Full range | 2 | | | |
| | | FK and J packages | $V_O = 0$ to 2.5 V, $R_L = 600\ \Omega$ | 25°C | 1 | 65 | | |
| | | | | Full range | 0.5 | | | |
| | | | $V_O = 0$ to − 2.5 V, $R_L = 600\ \Omega$ | 25°C | 1 | 16 | | |
| | | | | Full range | 0.5 | | | |
| | | D and N packages | $V_O = 0$ to 2 V, $R_L = 100\ \Omega$ | 25°C | 0.75 | 45 | | |
| | | | | Full range | 0.25 | | | |
| | | | $V_O = 0$ to − 2 V, $R_L = 100\ \Omega$ | 25°C | 0.4 | 3 | | |
| | | | | Full range | 0.15 | | | |

†Full range is − 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 5$ V (unless otherwise noted) (continued)

| PARAMETER | | TEST CONDITIONS | | $T_A$[†] | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | $I_O = 0$ | | 25°C | | 560 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min, | $R_S = 50\ \Omega$ | 25°C | 65 | 82 | | dB |
| | | | | Full range | 60 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 5$ V to $\pm 20$ V,<br>$R_S = 50\ \Omega$ | | 25°C | 75 | 93 | | dB |
| | | | | Full range | 65 | | | |
| $I_{CC}$ | Supply current (four amplifiers) | $V_O = 0$, | No load | 25°C | | 1.12 | 1.3 | mA |
| | | | | Full range | | | 1.3 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range (four amplifiers) | | | Full range | | 144 | | µA |
| $V_{o1}/V_{o2}$ | Crosstalk attenuation | $A_{VD} = 1000$, | f = 1 kHz | 25°C | | 120 | | dB |

[†] Full range is – 55°C to 125°C.

## operating characteristics, $V_{CC\pm} = \pm 5$ V, $T_A = 25°C$

| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L = 10\ k\Omega$, | $C_L = 100$ pF | | 3.4 | | V/µs |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S = 100\ \Omega$ | | 59 | | nV/√Hz |
| | | f = 1 kHz, | $R_S = 100\ \Omega$ | | 43 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | | 1.1 | | µV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | | 1 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD} = 2$,<br>$V_{O(PP)} = 2$ V, | f = 10 kHz,<br>$R_L = 10\ k\Omega$ | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L = 10\ k\Omega$, | $C_L = 100$ pF | | 1.8 | | MHz |
| | | $R_L = 600\ \Omega$, | $C_L = 100$ pF | | 1.3 | | µs |
| | Settling time | ε = 0.1% | | | 5 | | |
| | | ε = 0.01% | | | 10 | | kHz |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD} = 1$, | $R_L = 10\ k\Omega$ | | 140 | | |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L = 10\ k\Omega$, | $C_L = 100$ pF | | 58° | | |
| | | $R_L = 600\ \Omega$, | $C_L = 100$ pF | | 75° | | |

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2064M | $V_{IC} = 0$, | $R_S = 50\ \Omega$ | 25°C | | 0.9 | 6 | mV |
| | | | | | Full range | | | 8 | |
| | | TLE2064AM | | | 25°C | | 0.9 | 4 | |
| | | | | | Full range | | | 6 | |
| | | TLE2064BM | | | 25°C | | 0.7 | 2 | |
| | | | | | Full range | | | 4 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | | Full range | | 6 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | | 25°C | | 0.04 | | µV/mo |
| $I_{IO}$ | Input offset current | | | | 25°C | | 2 | | pA |
| | | | | | Full range | | | 20 | nA |
| $I_{IB}$ | Input bias current | | | | 25°C | | 4 | | pA |
| | | | | | Full range | | | 40 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | | 25°C | − 11<br>to<br>13 | − 12<br>to<br>16 | | V |
| | | | | | Full range | − 11<br>to<br>13 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | | 25°C | 13 | 13.7 | | V |
| | | | | | Full range | 12.5 | | | |
| | | | $R_L = 600\ \Omega$ | | 25°C | 12.5 | 13.2 | | |
| | | | | | Full range | 12 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | | 25°C | − 13 | − 13.7 | | V |
| | | | | | Full range | − 12.5 | | | |
| | | | $R_L = 600\ \Omega$ | | 25°C | − 13 | − 13 | | |
| | | | | | Full range | − 12.5 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 10$ V, | $R_L = 10\ k\Omega$ | 25°C | 30 | 230 | | V/mV |
| | | | | | Full range | 20 | | | |
| | | | $V_O = 0$ to 8 V, | $R_L = 600\ \Omega$ | 25°C | 25 | 100 | | |
| | | | | | Full range | 7 | | | |
| | | | $V_O = 0$ to − 8 V, | $R_L = 600\ \Omega$ | 25°C | 3 | 25 | | |
| | | | | | Full range | 1 | | | |
| $r_i$ | Input resistance | | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | | 25°C | | 560 | | Ω |
| CMRR | Common-mode rejection ratio | | $V_{IC} = V_{ICR}$ min, | $R_S = 50\ \Omega$ | 25°C | 72 | 90 | | dB |
| | | | | | Full range | 65 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to $\pm 15$ V,<br>$R_S = 50\ \Omega$ | | 25°C | 75 | 93 | | dB |
| | | | | | Full range | 65 | | | |
| $I_{CC}$ | Supply current (four amplifiers) | | $V_O = 0$, | No load | 25°C | | 1.25 | 1.4 | mA |
| | | | | | Full range | | | 1.5 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range (four amplifiers) | | | | Full range | | 194 | | µA |
| $V_{o1}/V_{o2}$ | Crosstalk attenuation | | $A_{VD} = 1000$, | f = 1 kHz | 25°C | | 120 | | dB |

† Full range is – 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150$°C extrapolated to $T_A = 25$°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | 2.6 | 3.4 | | V/μs |
| | | | | Full range | 1.8 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S$ = 100 Ω | 25°C | | 70 | | nV/√Hz |
| | | f = 1 kHz, | $R_S$ = 100 Ω | | | 40 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | 25°C | | 1.1 | | μV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | 25°C | | 1.1 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD}$ = 2,<br>$V_{O(PP)}$ = 2 V, | f = 10 kHz,<br>$R_L$ = 10 kΩ | 25°C | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 2 | | MHz |
| | | $R_L$ = 600 Ω, | $C_L$ = 100 pF | | | 1.5 | | |
| | Settling time | ε = 0.1% | | 25°C | | 5 | | μs |
| | | ε = 0.01% | | | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD}$ = 1, | $R_L$ = 10 kΩ | 25°C | | 40 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | 25°C | | 60° | | |
| | | $R_L$ = 600 Ω, | $C_L$ = 100 pF | | | 70° | | |

† Full range is – 55°C to 125°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 20$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2064M | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 1 | 6 | mV |
| | | | | Full range | | | 8 | |
| | | TLE2064AM | | 25°C | | 1 | 4.6 | |
| | | | | Full range | | | 6.6 | |
| | | TLE2064BM | | 25°C | | 0.7 | 2.2 | |
| | | | | Full range | | | 4.2 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | μV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | μV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 3 | | pA |
| | | | | Full range | | | 20 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 5 | | pA |
| | | | | Full range | | | 40 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | −15 to 16.5 | −17 to 21 | | V |
| | | | | Full range | −15 to 16.5 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 18 | 18.7 | | V |
| | | | | Full range | 17.5 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | 15 | 18.1 | | |
| | | | | Full range | 12 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | −18 | −18.7 | | V |
| | | | | Full range | −17.5 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | −15 | −18 | | |
| | | | | Full range | −12 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 15$ V, $R_L = 10\ k\Omega$ | 25°C | 30 | 280 | | V/mV |
| | | | | Full range | 20 | | | |
| | | | $V_O = 0$ to 10 V, $R_L = 600\ \Omega$ | 25°C | 25 | 80 | | |
| | | | | Full range | 10 | | | |
| | | | $V_O = 0$ to −10 V, $R_L = 600\ \Omega$ | 25°C | 3 | 20 | | |
| | | | | Full range | 1 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | 25°C | | 560 | | Ω |
| CMRR | Common-mode rejection ratio | | $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 25°C | 75 | 91 | | dB |
| | | | | Full range | 65 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to ±20 V, $R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | | | Full range | 65 | | | |
| $I_{CC}$ | Supply current (four amplifiers) | | $V_O = 0$, No load | 25°C | | 1.32 | 1.5 | mA |
| | | | | Full range | | | 1.6 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range (four amplifiers) | | | Full range | | 212 | | μA |
| $V_{o1}/V_{o2}$ | Crosstalk attenuation | | $A_{VD} = 1000$, f = 1 kHz | 25°C | | 120 | | dB |

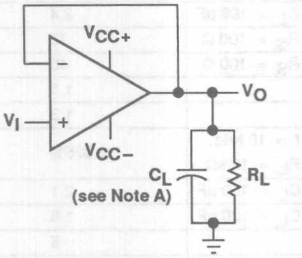
† Full range is − 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics, $V_{CC\pm} = \pm 20$ V, $T_A = 25°C$

| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain (see Figure 1) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | | 3.4 | | V/µs |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | f = 10 Hz, | $R_S$ = 100 Ω | | 75 | | nV/√Hz |
| | | f = 1 kHz, | $R_S$ = 100 Ω | | 40 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | | 1.1 | | µV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | | 1.3 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD}$ = 2,<br>$V_{O(PP)}$ = 2 V, | f = 10 kHz,<br>$R_L$ = 10 kΩ | | 0.025% | | |
| $B_1$ | Unity-gain bandwidth (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | | 2.1 | | MHz |
| | | $R_L$ = 600 Ω, | $C_L$ = 100 pF | | 1.6 | | |
| | Settling time | ε = 0.1% | | | 5 | | µs |
| | | ε = 0.01% | | | 10 | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $A_{VD}$ = 1, | $R_L$ = 10 kΩ | | 28 | | kHz |
| $\phi_m$ | Phase margin at unity gain (see Figure 3) | $R_L$ = 10 kΩ, | $C_L$ = 100 pF | | 60° | | |
| | | $R_L$ = 600 Ω, | $C_L$ = 100 pF | | 70° | | |

## PARAMETER MEASUREMENT INFORMATION



NOTE A: $C_L$ includes fixture capacitance.

**Figure 1. Slew Rate Test Circuit**

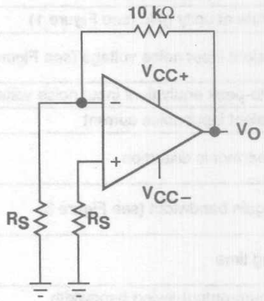
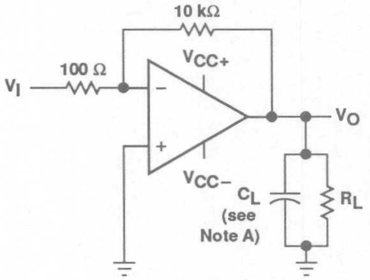


**Figure 2. Noise Voltage Test Circuit**



NOTE A: $C_L$ includes fixture capacitance.

**Figure 3. Unity-Gain Bandwidth and Phase Margin Test Circuit**

### typical values

Typical values as presented in this data sheet represent the median (50% point) of device parametric performance.

### input bias and offset current

At the picoampere bias current level typical of the TLE2064, TLE2064A, and TLE2064B, accurate measurement of the bias current becomes difficult. Not only does this measurement require a picoammeter, but test socket leakages can easily exceed the actual device bias currents. To accurately measure these small currents, Texas Instruments uses a two-step process. The socket leakage is measured using picoammeters with bias voltages applied but with no device in the socket. The device is then inserted into the socket and a second test that measures both the socket leakage and the device input bias current is performed. The two measurements are then subtracted algebraically to determine the bias current of the device.

## TYPICAL CHARACTERISTICS

### table of graphs

| | | | FIGURE |
|---|---|---|---|
| $V_{IO}$ | Input offset voltage | Distribution | 4 |
| $I_{IB}$ | Input bias current | vs Common-mode voltage | 5 |
| | | vs Temperature | 6 |
| $I_{IO}$ | Input offset current | vs Temperature | 6 |
| $V_{ICR}$ | Common-mode input voltage range | vs Temperature | 7 |
| $V_{OM}$ | Maximum peak output voltage swing | vs Output current | 8, 9 |
| | | vs Supply voltage | 10, 11, 12 |
| $V_{O(PP)}$ | Maximum peak-to-peak output voltage | vs Frequency | 13, 14, 15 |
| $A_{VD}$ | Differential voltage amplification | vs Frequency | 16 |
| | | vs Temperature | 17 |
| $I_{OS}$ | Short-circuit output current | vs Time | 18 |
| | | vs Temperature | 19 |
| $z_o$ | Output impedance | vs Frequency | 20 |
| CMRR | Common-mode rejection ratio | vs Frequency | 21 |
| $I_{CC}$ | Supply current | vs Supply voltage | 22 |
| | | vs Temperature | 23 |
| | Pulse response | Small-signal | 24, 25 |
| | | Large-signal | 26, 27 |
| | Noise voltage (referred to input) | 0.1 to 10 Hz | 28 |
| $V_n$ | Equivalent input noise voltage | vs Frequency | 29 |
| THD | Total harmonic distortion | vs Frequency | 30, 31 |
| $B_1$ | Unity-gain bandwidth | vs Supply voltage | 32 |
| | | vs Temperature | 33 |
| $\phi_m$ | Phase margin | vs Supply voltage | 34 |
| | | vs Load capacitance | 35 |
| | | vs Temperature | 36 |
| $\phi$ | Phase shift | vs Frequency | 16 |

## TYPICAL CHARACTERISTICS†

TLE2064
DISTRIBUTION OF
INPUT OFFSET VOLTAGE

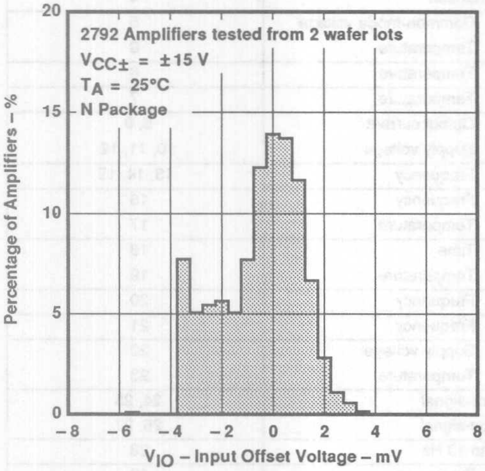


Figure 4

INPUT BIAS CURRENT
vs
COMMON-MODE INPUT VOLTAGE

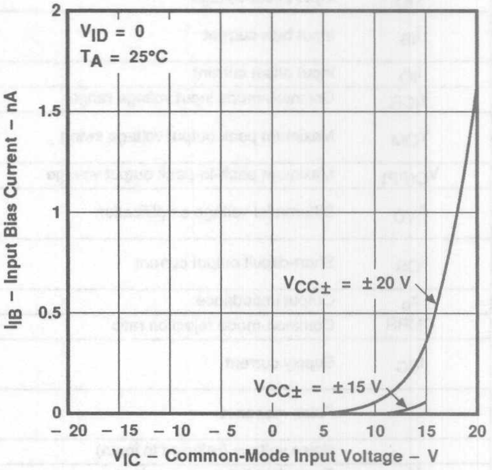


Figure 5

INPUT BIAS CURRENT
and INPUT OFFSET CURRENT
vs
FREE-AIR TEMPERATURE

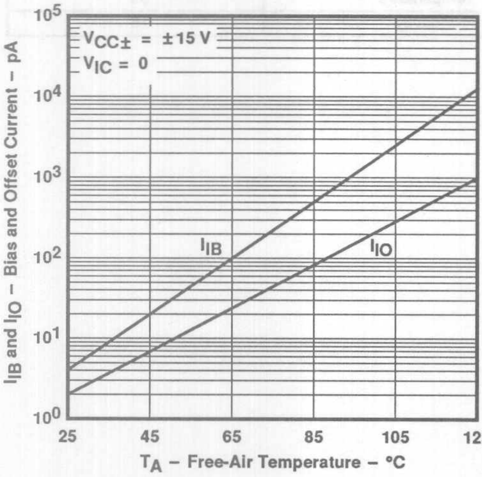


Figure 6

COMMON-MODE INPUT VOLTAGE RANGE
vs
FREE-AIR TEMPERATURE

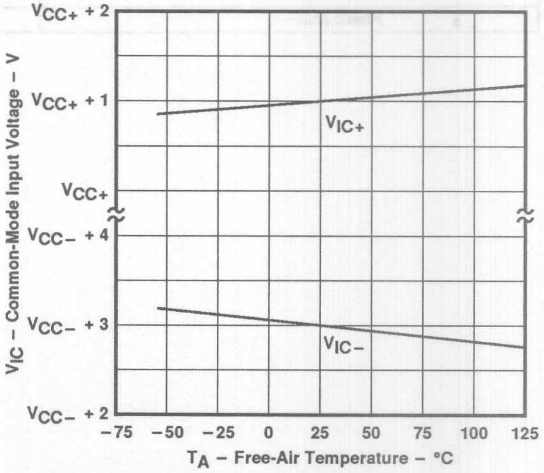


Figure 7

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†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS

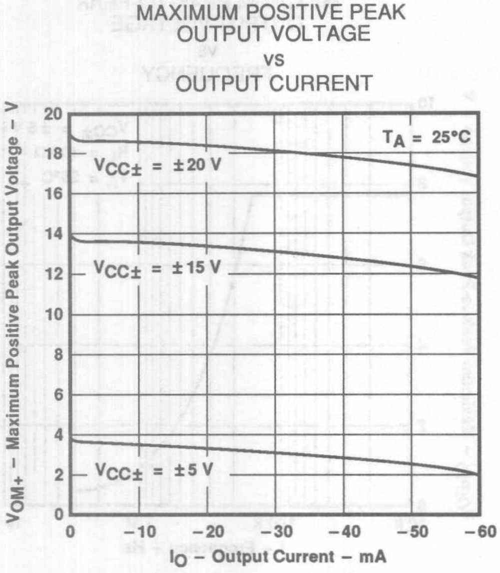

Figure 8

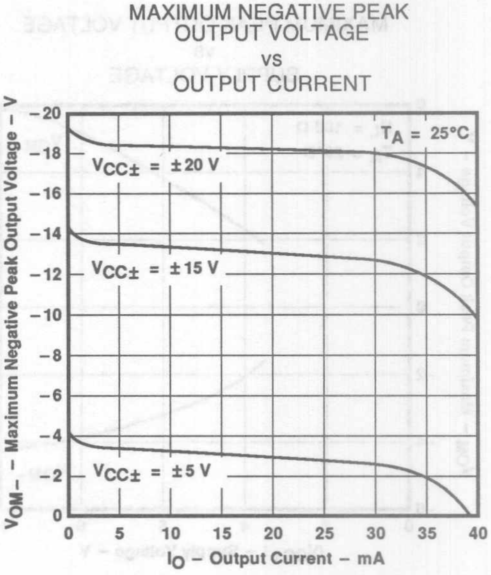

Figure 9

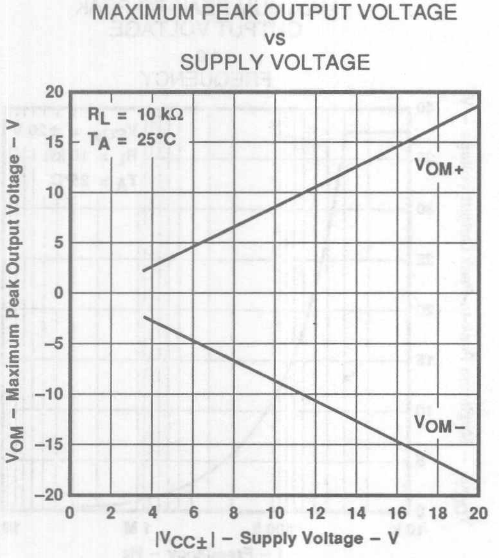

Figure 10

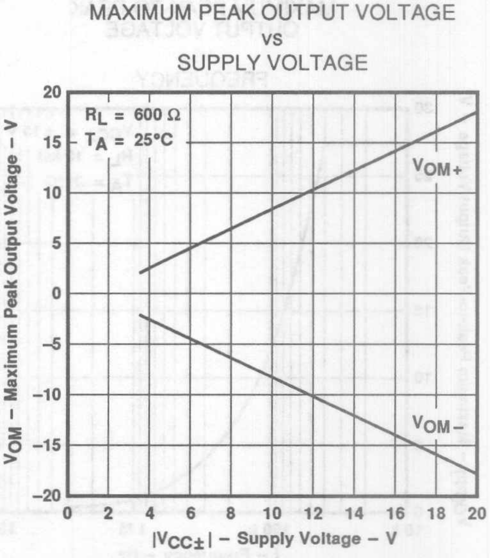

Figure 11

## TYPICAL CHARACTERISTICS

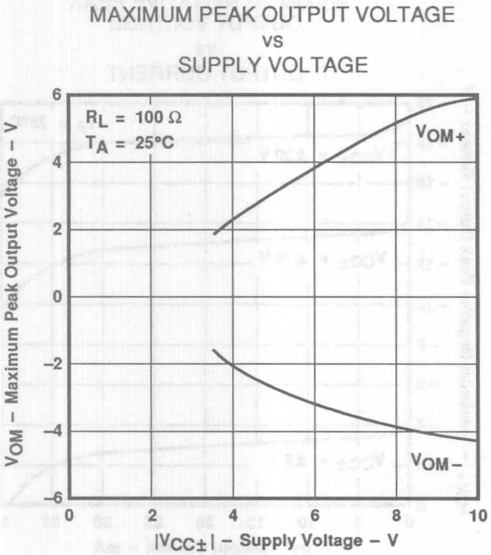

Figure 12

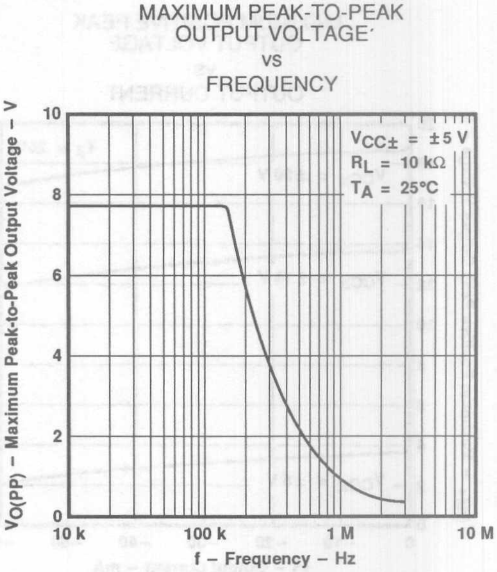

Figure 13

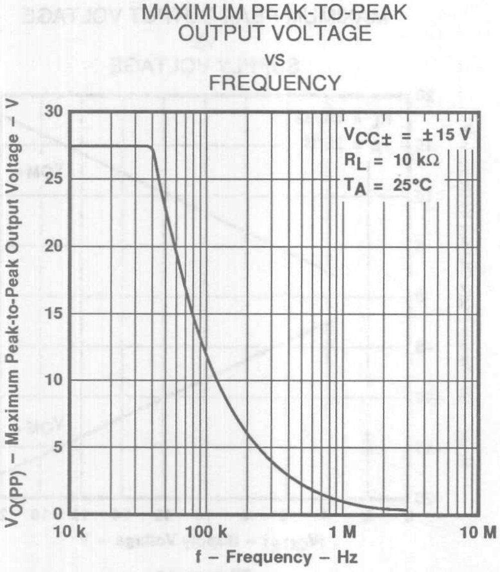

Figure 14

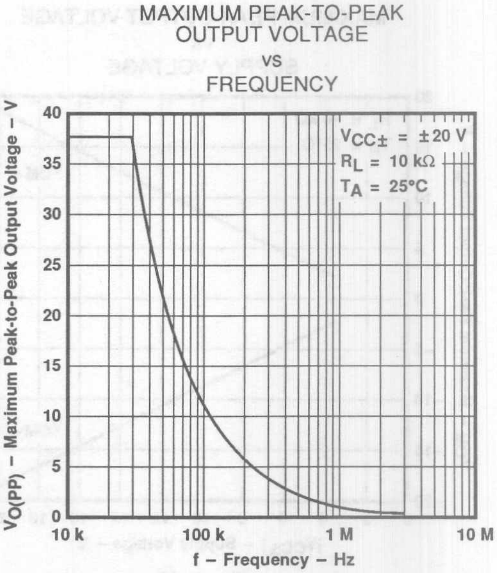

Figure 15

## TYPICAL CHARACTERISTICS†

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION and PHASE SHIFT
vs
FREQUENCY

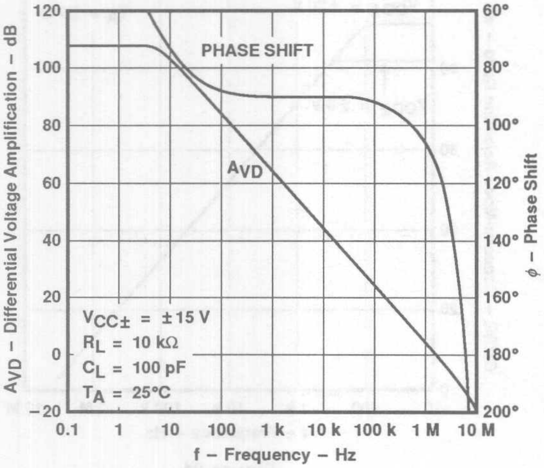

Figure 16

LARGE-SIGNAL VOLTAGE AMPLIFICATION
vs
FREE-AIR TEMPERATURE

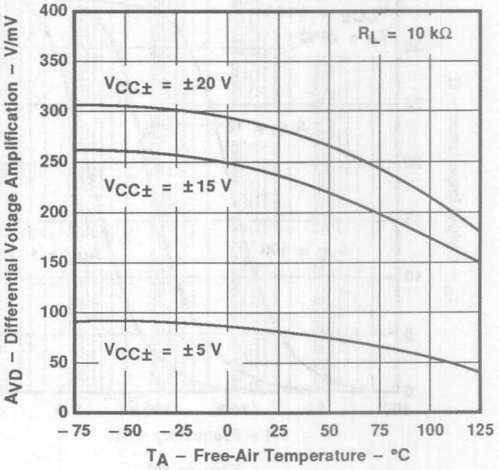

Figure 17

SHORT-CIRCUIT OUTPUT CURRENT
vs
ELAPSED TIME

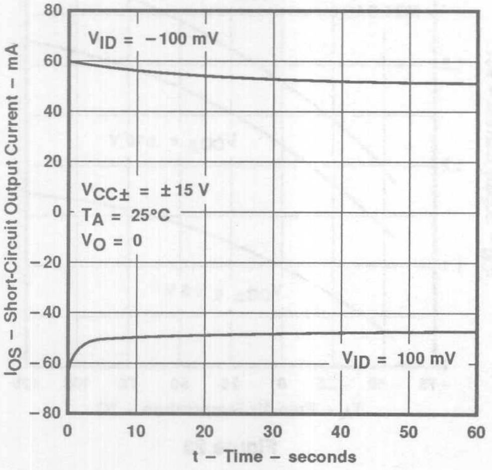

Figure 18

SHORT-CIRCUIT OUTPUT CURRENT
vs
FREE-AIR TEMPERATURE

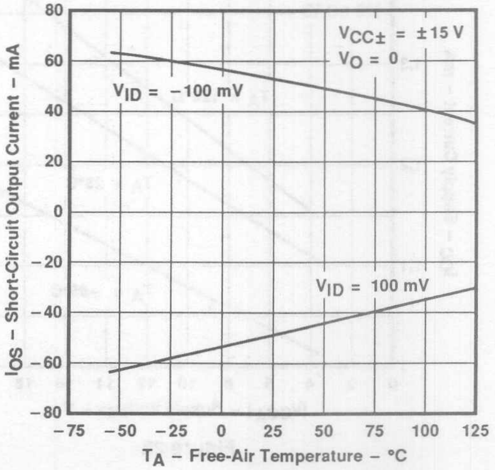

Figure 19

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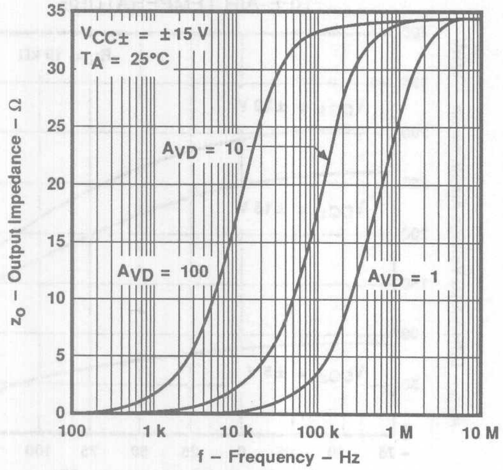
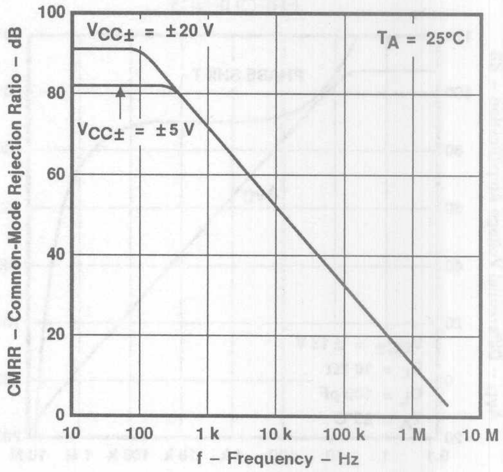
† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†



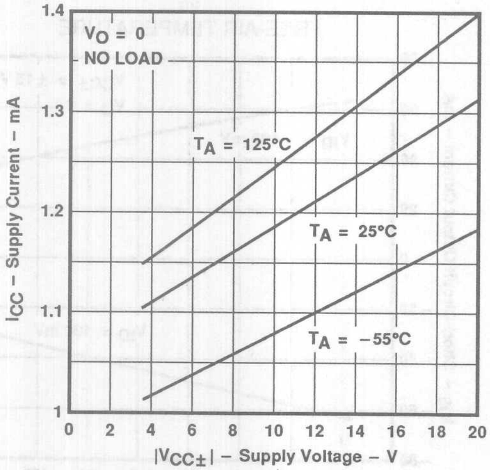
OUTPUT IMPEDANCE
vs
FREQUENCY

Figure 20



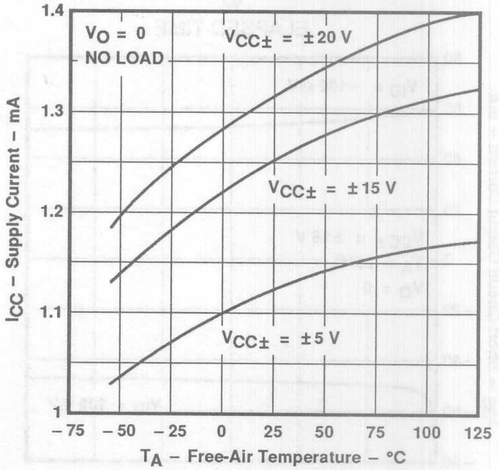
COMMON-MODE REJECTION RATIO
vs
FREQUENCY

Figure 21



SUPPLY CURRENT
vs
SUPPLY VOLTAGE

Figure 22



SUPPLY CURRENT
vs
FREE-AIR TEMPERATURE

Figure 23

---

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS

### VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE

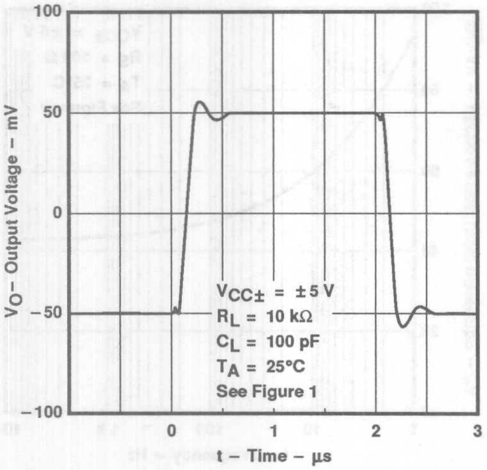


Figure 24

### VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE

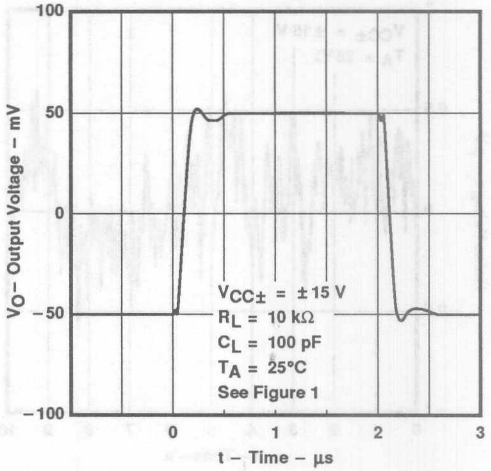


Figure 25

### VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSE

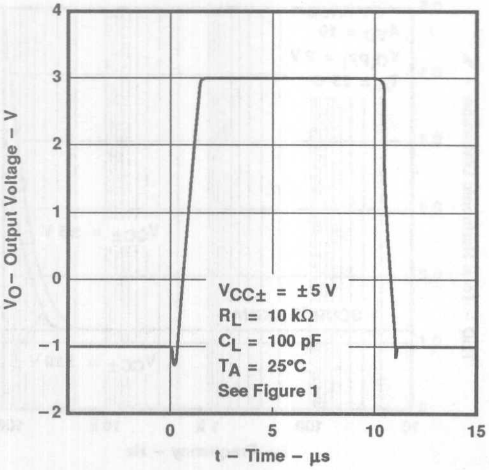


Figure 26

### VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSE

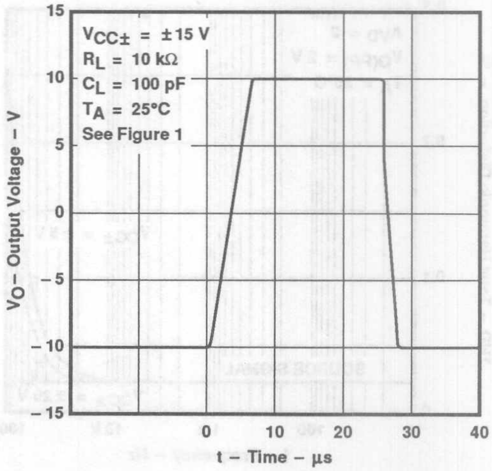


Figure 27

## TYPICAL CHARACTERISTICS

NOISE VOLTAGE
(REFERRED TO INPUT)
0.1 TO 10 Hz

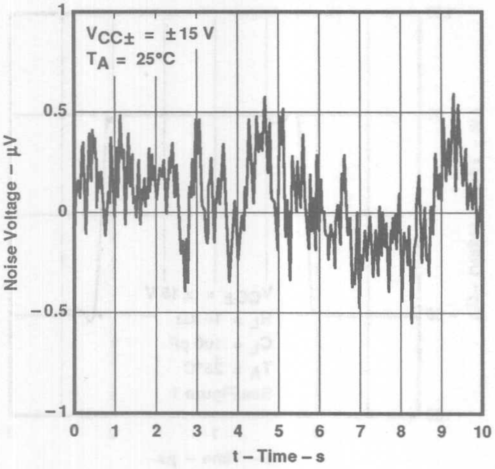


Figure 28

EQUIVALENT INPUT NOISE VOLTAGE
vs
FREQUENCY

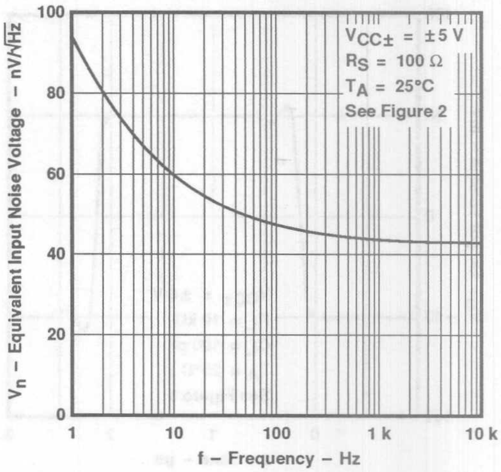


Figure 29

TOTAL HARMONIC DISTORTION
vs
FREQUENCY

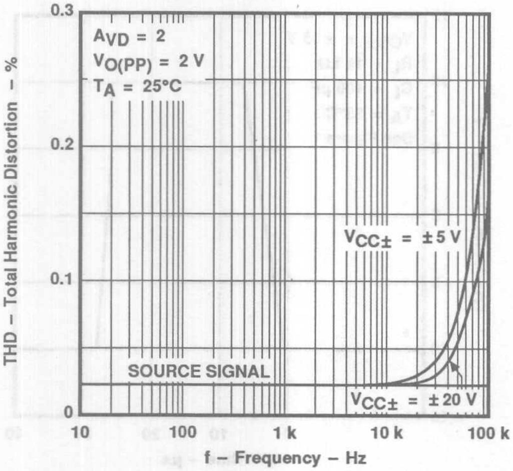


Figure 30

TOTAL HARMONIC DISTORTION
vs
FREQUENCY

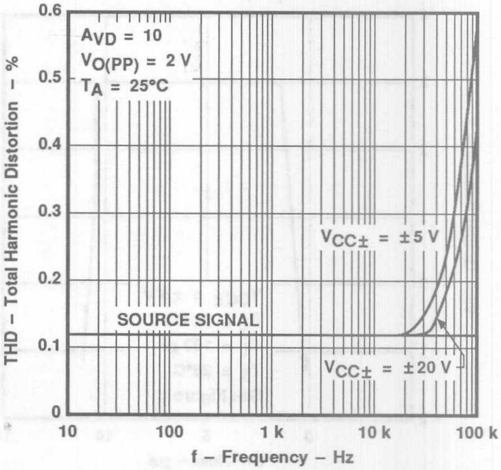


Figure 31

## TYPICAL CHARACTERISTICS†

UNITY-GAIN BANDWIDTH
vs
SUPPLY VOLTAGE

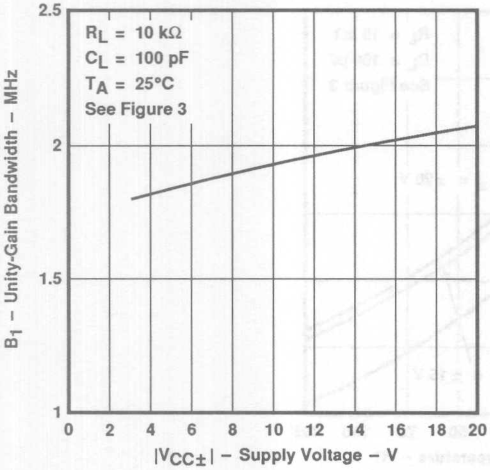


Figure 32

UNITY-GAIN BANDWIDTH
vs
FREE-AIR TEMPERATURE

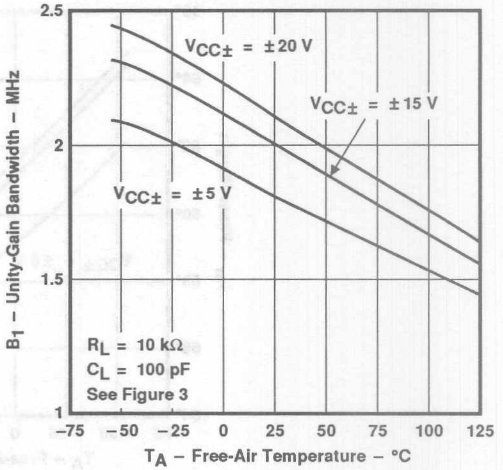


Figure 33

PHASE MARGIN
vs
SUPPLY VOLTAGE

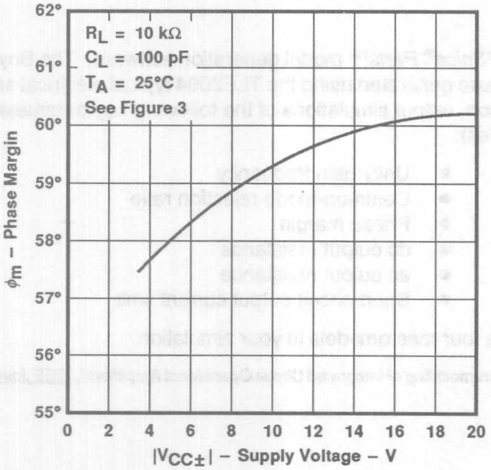


Figure 34

PHASE MARGIN
vs
LOAD CAPACITANCE

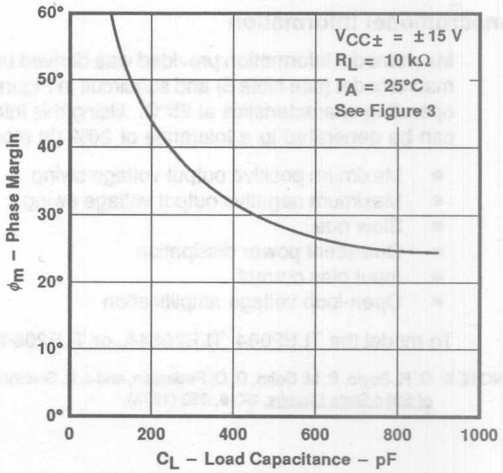


Figure 35

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† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

PHASE MARGIN
vs
FREE-AIR TEMPERATURE

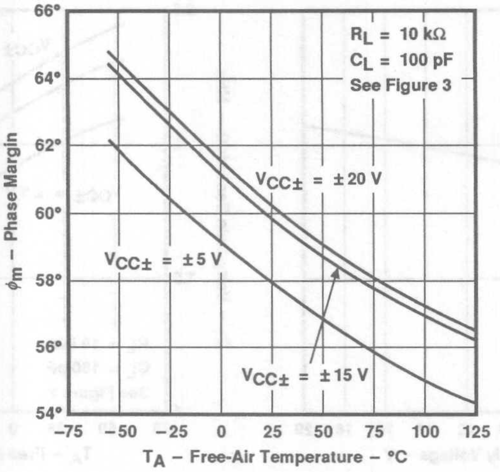


Figure 36

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## APPLICATION INFORMATION

### macromodel information

Macromodel information provided was derived using *PSpice® Parts™* model generation software. The Boyle macromodel (see Note 5) and subcircuit in Figure 37 were generated using the TLE2064 typical electrical and operating characteristics at 25°C. Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

- Maximum positive output voltage swing
- Maximum negative output voltage swing
- Slew rate
- Quiescent power dissipation
- Input bias current
- Open-loop voltage amplification
- Unity gain frequency
- Common-mode rejection ratio
- Phase margin
- dc output resistance
- ac output resistance
- Short-circuit output current limit

To model the TLE2064, TLE2064A, or TLE2064B, use four macromodels in your simulation.

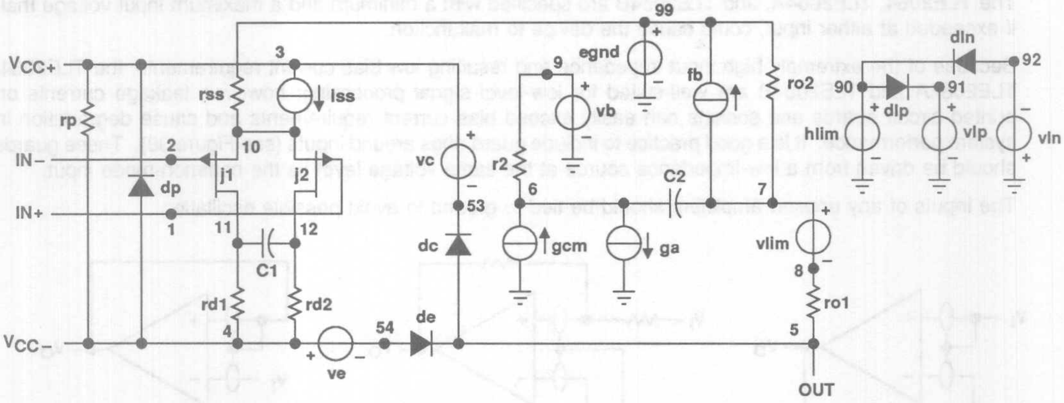
NOTE 5: G. R. Boyle, B. M. Cohn, D. O. Pederson, and J. E. Solomon, "Macromodeling of Integrated Circuit Operational Amplifiers", IEEE Journal of Solid-State Circuits, SC-9, 353 (1974).

*PSpice* is a registered trademark of MicroSim Corporation.
*Parts* is a trademark of MicroSim Corporation.

Macromodels, simulation models, or other models provided by TI, directly or indirectly, are not warranted by TI as fully representing all of the specifications and operating characteristics of the semiconductor product to which the model relates.

## APPLICATION INFORMATION

### macromodel information (continued)



```
.subckt TLE2064  1 2 3 4 5
  c1    11 12 1.457E-12
  c2     6  7 15.00E-12
  dc     5 53 dx
  de    54  5 dx
  dlp   90 91 dx
  dln   92 90 dx
  dp     4  3 dx
  egnd  99  0 poly(2) (3,0) (4,0) 0 .5 .5
  fb     7 99 poly(5) vb vc ve vlp vln 0 4.357E6 -4E6 4E6 4E6 -4E6
  ga     6  0 11 12 188.5E-6
  gcm    0  6 10 99 3.352E-9
  iss    3 10 dc 51.00E-6
  hlim  90  0 vlim 1K
  j1    11  2 10 jx
  j2    12  1 10 jx
  r2     6  9 100.0E3
  rd1    4 11 5.305E3
  rd2    4 12 5.305E3
  ro1    8  5 280
  ro2    7 99 280
  rp     3  4 113.2E3
  rss   10 99 3.922E6
  vb     9  0 dc 0
  vc     3 53 dc 2
  ve    54  4 dc 2
  vlim   7  8 dc 0
  vlp   91  0 dc 50
  vln    0 92 dc 50
.model dx D(Is=800.0E-18)
.model jx PJF(Is=2.000E-12 Beta=423E-6 Vto=-1)
.ends
```

Figure 37. Boyle Macromodel and Subcircuit

## APPLICATION INFORMATION

### input characteristics

The TLE2064, TLE2064A, and TLE2064B are specified with a minimum and a maximum input voltage that, if exceeded at either input, could cause the device to malfunction.

Because of the extremely high input impedance and resulting low bias current requirements, the TLE2064, TLE2064A and TLE2064B are well-suited for low-level signal processing; however, leakage currents on printed circuit boards and sockets can easily exceed bias current requirements and cause degradation in system performance. It is a good practice to include guard rings around inputs (see Figure 38). These guards should be driven from a low-impedance source at the same voltage level as the common-mode input.

The inputs of any unused amplifiers should be tied to ground to avoid possible oscillation.

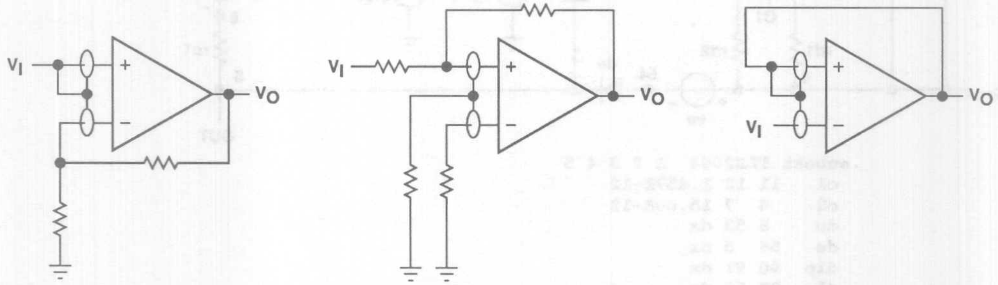


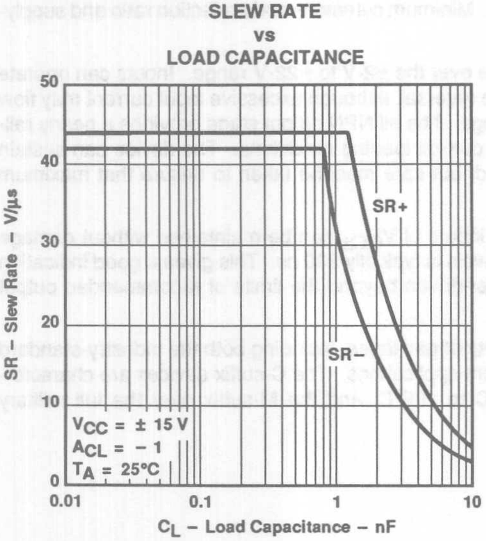
Figure 38. Use of Guard Rings

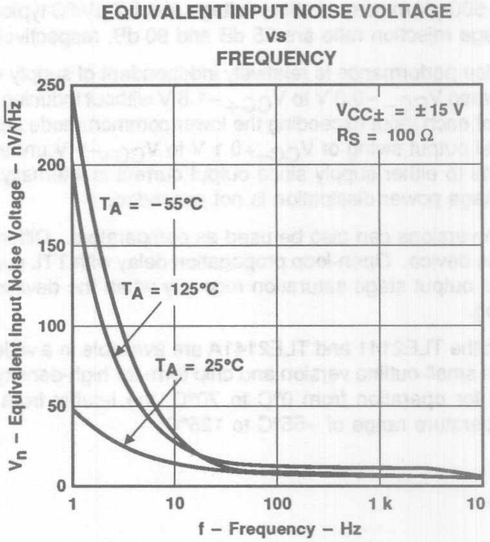
# TLE2141, TLE2141A
# EXCALIBUR LOW-NOISE HIGH-SPEED PRECISION OPERATIONAL AMPLIFIERS

D3652, NOVEMBER 1990 – REVISED FEBRUARY 1991

## available features

- Low Noise:
  10 Hz . . . 15 nV/√Hz
  1 kHz . . . 10.5 nV/√Hz
- 10,000-pF Load Capability
- 20-mA Min Short Circuit Output Current
- 30-V/µs Min Slew Rate
- High Gain-Bandwidth Product . . . 5.9 MHz
- Low $V_{IO}$ . . . 500 µV Max at 25°C
- Single or Split Supply . . . 4 V to 44 V
- Fast Settling Time . . . 340 ns to 0.1%
  400 ns to 0.01%
- Saturation Recovery . . . 150 ns
- Large Output Swing . . . $V_{CC-}$ + 0.1 V
  to $V_{CC+}$ – 1 V


SLEW RATE
vs
LOAD CAPACITANCE


EQUIVALENT INPUT NOISE VOLTAGE
vs
FREQUENCY

## description

The TLE2141 and TLE2141A are high-performance, internally compensated operational amplifiers built using Texas Instruments complementary bipolar Excalibur process. The TLE2141A is a tighter offset voltage grade of the TLE2141. Both are pin-compatible upgrades to standard industry products.

AVAILABLE OPTIONS

| | | PACKAGE | | | | | |
|---|---|---|---|---|---|---|---|
| $T_A$ | $V_{IO}$ max AT 25°C | SMALL-OUTLINE (D) | CHIP CARRIER (FK) | CERAMIC DIP (JG) | METAL CAN (L) | PLASTIC DIP (P) | CHIP FORM (Y) |
| 0°C to 70°C | 500 µV | TLE2141ACD | — | — | — | TLE2141ACP | TLE2141Y |
| | 900 µV | TLE2141CD | — | — | — | TLE2141CP | |
| – 40°C to 105°C | 500 µV | TLE2141AID | — | — | — | TLE2141AIP | |
| | 900 µV | TLE2141ID | — | — | — | TLE2141IP | |
| – 55°C to 125°C | 500 µV | TLE2141AMD | TLE2141AMFK | TLE2141AMJG | TLE2141AML | TLE2141AMP | |
| | 900 µV | TLE2141MD | TLE2141MFK | TLE2141MJG | TLE2141ML | TLE2141MP | |

D packages are available taped-and-reeled. Add "R" suffix to device type, (e.g., TLE2141ACDR).

PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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On products compliant to MIL-STD-883, Class B, all parameters are tested unless otherwise noted. On all other products, production processing does not necessarily include testing of all parameters.

## description (continued)

The design incorporates a patent-pending input stage that simultaneously achieves low audio band noise of 10.5 nV/$\sqrt{Hz}$ with a 10-Hz 1/f corner and symmetrical 40-V/µs slew rate typically with loads up to 800 pF. The resulting low distortion and high power-bandwidth are important in hi-fi audio applications. A fast settling time of 340 ns to 0.1% of a 10-V step with a 2-kΩ /100-pF load is useful in fast actuator/positioning drivers. Under similar test conditions, settling time to 0.01% is 400 ns.

The devices are stable with capacitive loads up to 10 nF, although the 6 MHz bandwidth decreases to 1.8 MHz at this high loading level. As such, the TLE2141 and TLE2141A are useful for low droop sample-and-holds and direct buffering of long cables, including 4-20 mA current loops.

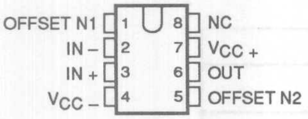
The special design also exhibits an improved insensitivity to inherent IC component mismatches as is evidenced by a 500-µV maximum offset voltage and 1.7-µV/°C typical drift. Minimum common-mode rejection ratio and supply-voltage rejection ratio are 85 dB and 90 dB, respectively.

Device performance is relatively independent of supply voltage over the ±2-V to ±22-V range. Inputs can operate between $V_{CC-}$ −0.3 V to $V_{CC+}$ −1.8 V without inducing phase reversal, although excessive input current may flow out of each input exceeding the lower common-mode input range. The all NPN output stage provides a nearly rail-to-rail output swing of $V_{CC-}$+0.1 V to $V_{CC+}$−1 V under light current loading conditions. The device can sustain shorts to either supply since output current is internally limited, but care must be taken to ensure that maximum package power dissipation is not exceeded.

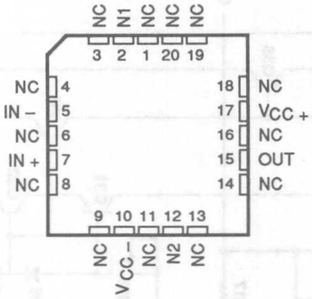
Both versions can also be used as comparators. Differential inputs of $V_{CC\pm}$ can be maintained without damage to the device. Open-loop propagation delay with TTL supply levels is typically 200 ns. This gives a good indication as to output stage saturation recovery when the device is over-driven beyond the limits of recommended output swing.

Both the TLE2141 and TLE2141A are available in a wide variety of packages, including both the industry-standard 8-pin small-outline version and chip form for high-density system applications. The C-suffix devices are characterized for operation from 0°C to 70°C, the I-suffix from −40°C to 105°C, and the M-suffix over the full military temperature range of −55°C to 125°C.

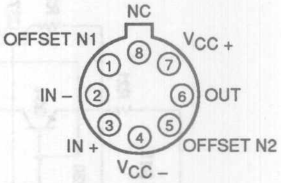
**D, JG, OR P PACKAGE**
**(TOP VIEW)**



**FK PACKAGE**
**(TOP VIEW)**

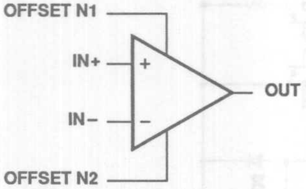


**L PACKAGE**
**(TOP VIEW)**



Pin 4 of the L package is in electrical contact with the case.

## symbol

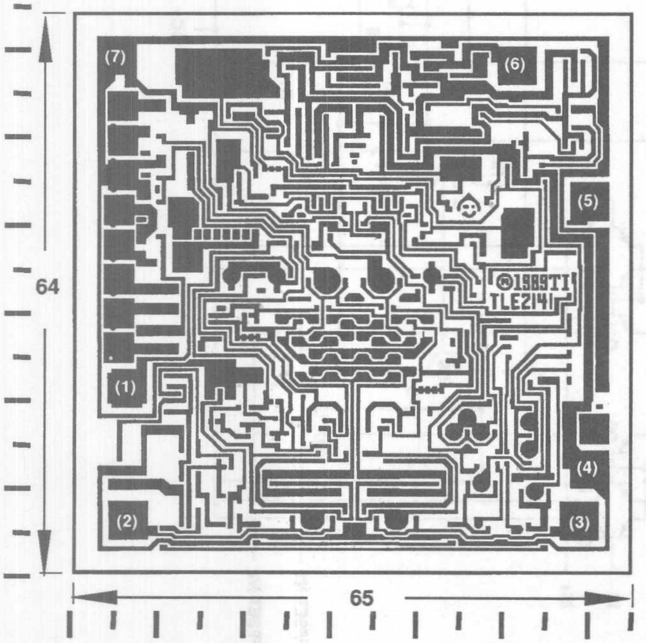


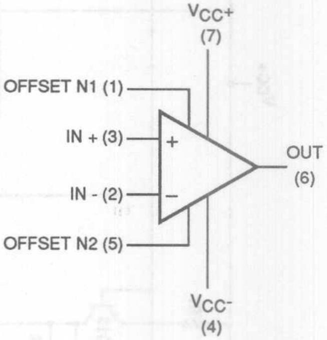
NC – No internal connection

## chip information

These chips, properly assembled, display characteristics similar to the TLE2141, (see electrical table on page 18). Thermal compression or ultrasonic bonding may be used on the doped aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.

**BONDING PAD ASSIGNMENTS**





**CHIP THICKNESS:**
**15 TYPICAL**

**BONDING PADS:**
**4 X 4 MINIMUM**

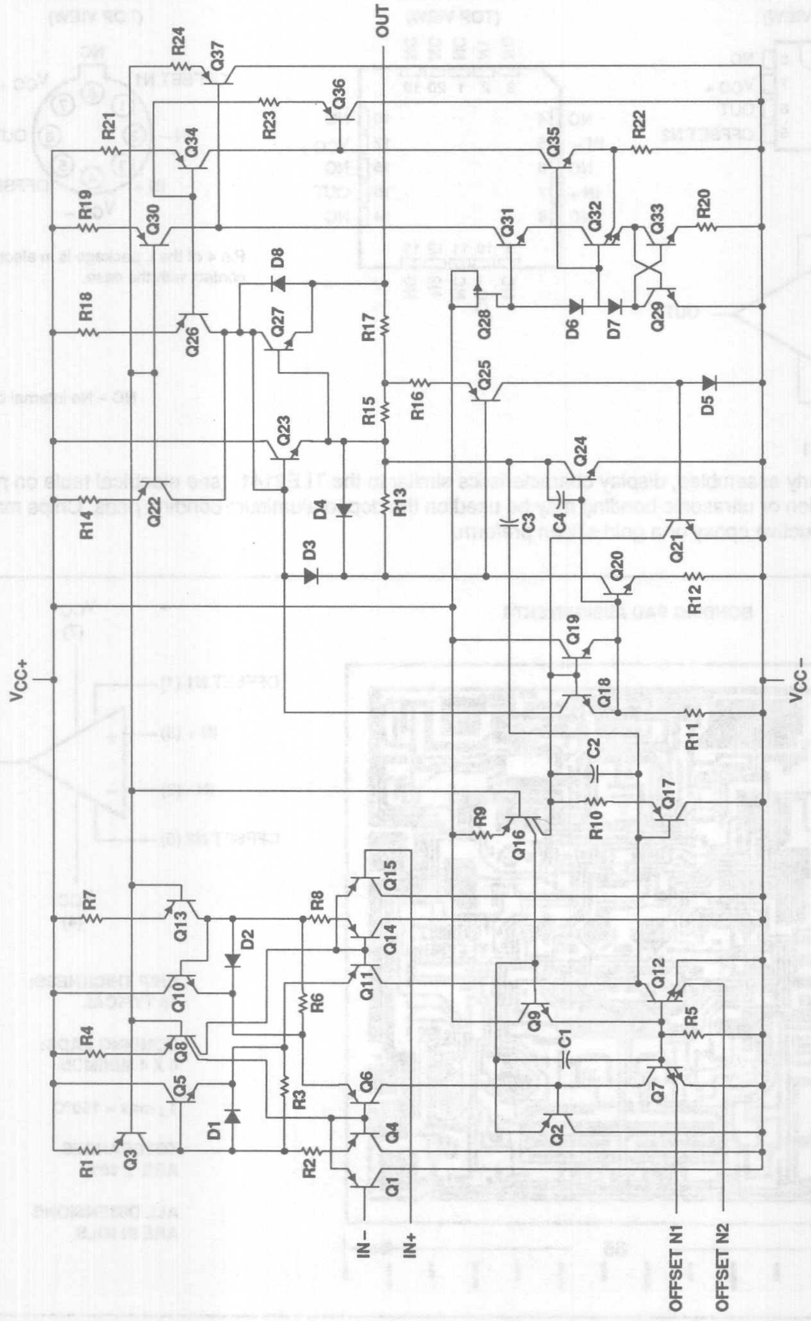
**$T_J$ max = 150°C**

**TOLERANCES**
**ARE ± 10%**

**ALL DIMENSIONS**
**ARE IN MILS**

# TLE2141, TLE2141A
# EXCALIBUR LOW-NOISE HIGH-SPEED PRECISION OPERATIONAL AMPLIFIERS

## equivalent schematic



## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|---|
| Supply voltage, $V_{CC+}$ (see Note 1) | 22 V |
| Supply voltage, $V_{CC-}$ | −22 V |
| Differential input voltage (see Note 2) | ±44 V |
| Input voltage range, $V_I$ (any input) | $V_{CC+}$ to $V_{CC-}$ − 0.3 V |
| Input current, $I_I$ (each input) | ±1 mA |
| Output current, $I_O$ | ±80 mA |
| Total current into $V_{CC+}$ terminal | 80 mA |
| Total current out of $V_{CC-}$ terminal | 80 mA |
| Duration of short-circuit current at (or below) 25°C (see Note 3) | unlimited |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range, $T_A$: C-suffix | 0°C to 70°C |
| I-suffix | −40°C to 105°C |
| M-suffix | −55°C to 125°C |
| Storage temperature range | −65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG or L package | 300°C |

NOTES:
1. All voltage values, except differential voltages, are with respect to the midpoint between $V_{CC+}$ and $V_{CC-}$.
2. Differential voltages are at the noninverting input with respect to the inverting input. Excessive current will flow if input is brought below $V_{CC-}$ − 0.3 V.
3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

### DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25°C$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25°C$ | $T_A = 70°C$ POWER RATING | $T_A = 105°C$ POWER RATING | $T_A = 125°C$ POWER RATING |
|---|---|---|---|---|---|
| D | 725 mW | 5.8 mW/°C | 464 mW | 261 mW | 145 mW |
| FK | 1375 mW | 11.0 mW/°C | 880 mW | 495 mW | 275 mW |
| JG | 1050 mW | 8.4 mW/°C | 672 mW | 378 mW | 210 mW |
| L | 650 mW | 5.2 mW/°C | 416 mW | 234 mW | 130 mW |
| P | 1000 mW | 8.0 mW/°C | 640 mW | 360 mW | 200 mW |

## recommended operating conditions

| | | C-SUFFIX | | I-SUFFIX | | M-SUFFIX | | UNIT |
|---|---|---|---|---|---|---|---|---|
| | | MIN | MAX | MIN | MAX | MIN | MAX | |
| Supply voltage, $V_{CC\pm}$ | | ± 2 | ± 22 | ± 2 | ± 22 | ± 2 | ± 22 | V |
| Common-mode input voltage, $V_{IC}$ | $V_{CC} = 5$ V | 0 | 2.9 | 0 | 2.7 | 0 | 2.7 | V |
| | $V_{CC\pm} = \pm 15$ V | − 15 | 12.9 | − 15 | 12.7 | − 15 | 12.7 | |
| Operating free-air temperature, $T_A$ | | 0 | 70 | − 40 | 105 | − 55 | 125 | °C |

## electrical characteristics at specified free-air temperature, $V_{CC}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2141C | | | TLE2141AC | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_O$ = 2.5 V, $R_S$ = 50 Ω,<br>$V_{IC}$ = 2.5 V | 25°C | | 225 | 1400 | | 200 | 1000 | μV |
| | | | Full range | | | 1700 | | | 1300 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 1.7 | | | 1.7 | | μV/°C |
| $I_{IO}$ | Input offset current | | 25°C | | 8 | 100 | | 8 | 100 | nA |
| | | | Full range | | | 150 | | | 150 | |
| $I_{IB}$ | Input bias current | | 25°C | | − 0.8 | − 2 | | − 0.8 | − 2 | μA |
| | | | Full range | | | − 2.1 | | | − 2.1 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S$ = 50 Ω | 25°C | 0 to 3 | − 0.3 to 3.2 | | 0 to 3 | − 0.3 to 3.2 | | V |
| | | | Full range | 0 to 2.9 | | | 0 to 2.9 | | | |
| $V_{OH}$ | High-level output voltage | $I_{OH}$ = − 150 μA | 25°C | 3.9 | 4.1 | | 3.9 | 4.1 | | V |
| | | | Full range | 3.8 | | | 3.8 | | | |
| | | $I_{OH}$ = − 1.5 mA | 25°C | 3.8 | 4 | | 3.8 | 4 | | |
| | | | Full range | 3.7 | | | 3.7 | | | |
| | | $I_{OH}$ = − 15 mA | 25°C | 3.2 | 3.7 | | 3.2 | 3.7 | | |
| | | | Full range | 3.2 | | | 3.2 | | | |
| $V_{OL}$ | Low-level output voltage | $I_{OL}$ = 150 μA | 25°C | | 75 | 125 | | 75 | 125 | mV |
| | | | Full range | | | 150 | | | 150 | |
| | | $I_{OL}$ = 1.5 mA | 25°C | | 150 | 225 | | 150 | 225 | |
| | | | Full range | | | 250 | | | 250 | |
| | | $I_{OL}$ = 15 mA | 25°C | | 1.2 | 1.6 | | 1.2 | 1.6 | V |
| | | | Full range | | | 1.7 | | | 1.7 | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_{CC}$ = ± 2.5 V, $R_L$ = 2 kΩ,<br>$V_O$ = 1 V to − 1.5 V | 25°C | 50 | 220 | | 50 | 220 | | V/mV |
| | | | Full range | 25 | | | 25 | | | |
| $r_i$ | Input resistance | | 25°C | | 70 | | | 70 | | MΩ |
| $c_i$ | Input capacitance | | 25°C | | 2.5 | | | 2.5 | | pF |
| $z_o$ | Open-loop output impedance | f = 1 MHz | 25°C | | 30 | | | 30 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC}$ = $V_{ICR}$ min,<br>$R_S$ = 50 Ω | 25°C | 85 | 118 | | 85 | 118 | | dB |
| | | | Full range | 80 | | | 80 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm}$ = ± 2.5 V to ± 15 V,<br>$R_S$ = 50 Ω | 25°C | 90 | 106 | | 90 | 106 | | dB |
| | | | Full range | 85 | | | 85 | | | |
| $I_{CC}$ | Supply current | $V_O$ = 2.5 V, No Load,<br>$V_{IC}$ = 2.5 V | 25°C | | 3.4 | 4.4 | | 3.4 | 4.4 | mA |
| | | | Full range | | | 4.6 | | | 4.6 | |

†Full range is 0°C to 70°C.

## operating characteristics at specified free-air temperature, $V_{CC} = 5$ V

| | PARAMETER | TEST CONDITIONS | | $T_A$ | TLE2141C | | | TLE2141AC | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR + | Positive slew rate | $A_{VD} = -1$, $R_L = 2\ \mathrm{k\Omega}^{\dagger}$, | | 25°C | | 45 | | | 45 | | V/μs |
| SR – | Negative slew rate | $C_L = 500$ pF | | | | 42 | | | 42 | | |
| | Settling time | $A_{VD} = -1$,<br>2.5-V Step | To 0.1% | 25°C | | 0.16 | | | 0.16 | | μs |
| | | | To 0.01% | | | 0.22 | | | 0.22 | | |
| $V_n$ | Equivalent input noise voltage | $R_S = 100\ \Omega$, $f = 10$ Hz | | 25°C | | 15 | | | 15 | | $\mathrm{nV}/\sqrt{\mathrm{Hz}}$ |
| | | $R_S = 100\ \Omega$, $f = 1$ kHz | | | | 10.5 | | | 10.5 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | $f = 0.1$ Hz to 1 Hz | | 25°C | | 0.48 | | | 0.48 | | μV |
| | | $f = 0.1$ Hz to 10 Hz | | | | 0.51 | | | 0.51 | | |
| $I_n$ | Equivalent input noise current | $f = 10$ Hz | | 25°C | | 1.92 | | | 1.92 | | $\mathrm{pA}/\sqrt{\mathrm{Hz}}$ |
| | | $f = 1$ kHz | | | | 0.5 | | | 0.5 | | |
| THD + N | Total harmonic distortion plus noise | $V_O = 1$ V to 3 V, $R_L = 2\ \mathrm{k\Omega}^{\dagger}$,<br>$A_{VD} = 2$, $f = 10$ kHz | | 25°C | | 0.0052 % | | | 0.0052 % | | |
| $B_1$ | Unity-gain bandwidth | $R_L = 2\ \mathrm{k\Omega}^{\dagger}$, $C_L = 100$ pF | | 25°C | | 5.9 | | | 5.9 | | MHz |
| | Gain-bandwidth product | $R_L = 2\ \mathrm{k\Omega}^{\dagger}$, $C_L = 100$ pF,<br>$f = 100$ kHz | | 25°C | | 5.8 | | | 5.8 | | MHz |
| $B_{OM}$ | Maximum output-swing bandwidth | $R_L = 2\ \mathrm{k\Omega}^{\dagger}$, $V_{O(PP)} = 2$ V,<br>$A_{VD} = 1$, $C_L = 100$ pF | | 25°C | | 6.6 | | | 6.6 | | MHz |
| $\phi_m$ | Phase margin at unity-gain | $R_L = 2\ \mathrm{k\Omega}^{\dagger}$, $C_L = 100$ pF | | 25°C | | 57° | | | 57° | | |

$^{\dagger}R_L$ terminates at 2.5 V.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TLE2141C | | | TLE2141AC | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC} = 0$,<br>$R_S = 50\ \Omega$,<br>$V_O = 0$ | | 25°C | | 200 | 900 | | 175 | 500 | μV |
| | | | | Full range | | | 1300 | | | 800 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 1.7 | | | 1.7 | | μV/°C |
| $I_{IO}$ | Input offset current | | | 25°C | | 7 | 100 | | 7 | 100 | nA |
| | | | | Full range | | | 150 | | | 150 | |
| $I_{IB}$ | Input bias current | | | 25°C | | − 0.7 | − 1.5 | | − 0.7 | − 1.5 | μA |
| | | | | Full range | | | − 1.6 | | | − 1.6 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | | 25°C | − 15 to 13 | − 15.3 to 13.2 | | − 15 to 13 | − 15.3 to 13.2 | | V |
| | | | | Full range | − 15 to 12.9 | − 15.3 to 13.1 | | − 15 to 12.9 | − 15.3 to 13.1 | | |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $I_O = -150\ \mu A$ | | 25°C | 13.8 | 14.1 | | 13.8 | 14.1 | | V |
| | | | | Full range | 13.7 | | | 13.7 | | | |
| | | $I_O = -1.5$ mA | | 25°C | 13.7 | 14 | | 13.7 | 14 | | |
| | | | | Full range | 13.6 | | | 13.6 | | | |
| | | $I_O = -15$ mA | | 25°C | 13.1 | 13.7 | | 13.1 | 13.7 | | |
| | | | | Full range | 13 | | | 13 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | $I_O = 150\ \mu A$ | | 25°C | − 14.7 | − 14.9 | | − 14.7 | − 14.9 | | V |
| | | | | Full range | − 14.6 | | | − 14.6 | | | |
| | | $I_O = 1.5$ mA | | 25°C | − 14.5 | − 14.8 | | − 14.5 | − 14.8 | | |
| | | | | Full range | − 14.4 | | | − 14.4 | | | |
| | | $I_O = 15$ mA | | 25°C | − 13.4 | − 13.8 | | − 13.4 | − 13.8 | | |
| | | | | Full range | − 13.3 | | | − 13.3 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = \pm 10$ V | | 25°C | 100 | 450 | | 100 | 450 | | V/mV |
| | | | | Full range | 75 | | | 75 | | | |
| $r_i$ | Input resistance | $R_L = 2\ k\Omega$ | | 25°C | | 65 | | | 65 | | MΩ |
| $c_i$ | Input capacitance | | | 25°C | | 2.5 | | | 2.5 | | pF |
| $z_o$ | Open-loop output impedance | f = 1 MHz | | 25°C | | 30 | | | 30 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min,<br>$R_S = 50\ \Omega$ | | 25°C | 85 | 108 | | 85 | 108 | | dB |
| | | | | Full range | 80 | | | 80 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 2.5$ V to ± 15 V,<br>$R_S = 50\ \Omega$ | | 25°C | 90 | 106 | | 90 | 106 | | dB |
| | | | | Full range | 85 | | | 85 | | | |
| $I_{OS}$ | Short-circuit output current | $V_O = 0$ | $V_{ID} = 1$ V | 25°C | − 25 | − 50 | | − 25 | − 50 | | mA |
| | | | $V_{ID} = -1$ V | | 20 | 31 | | 20 | 31 | | |
| $I_{CC}$ | Supply current | $V_O = 0$, | No Load | 25°C | | 3.5 | 4.5 | | 3.5 | 4.5 | mA |
| | | | | Full range | | | 4.7 | | | 4.7 | |

†Full range is 0°C to 70°C.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V

| | PARAMETER | TEST CONDITIONS | $T_A$ | TLE2141C | | | TLE2141AC | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR + | Positive slew rate | $A_{VD} = -1$, $R_L = 2\ k\Omega$, $C_L = 500$ pF | 25°C | 30 | 45 | | 30 | 45 | | V/μs |
| SR − | Negative slew rate | | 25°C | 30 | 42 | | 30 | 42 | | |
| | Settling time | $A_{VD} = -1$, 10 V Step, To 0.1% | 25°C | | 0.34 | | | 0.34 | | μs |
| | | To 0.01% | | | 0.4 | | | 0.4 | | |
| $V_n$ | Equivalent input noise voltage | $R_S = 100\ \Omega$, f = 10 Hz | 25°C | | 15 | | | 15 | | nV/√Hz |
| | | $R_S = 100\ \Omega$, f = 1 kHz | | | 10.5 | | | 10.5 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz | 25°C | | 0.48 | | | 0.48 | | μV |
| | | f = 0.1 Hz to 10 Hz | | | 0.51 | | | 0.51 | | |
| $I_n$ | Equivalent input noise current | f = 10 Hz | 25°C | | 1.89 | | | 1.89 | | pA/√Hz |
| | | f = 1 kHz | | | 0.47 | | | 0.47 | | |
| THD + N | Total harmonic distortion plus noise | $V_{O(PP)} = 20$ V, $R_L = 2\ k\Omega$, $A_{VD} = 10$, f = 10 kHz | 25°C | | 0.01% | | | 0.01% | | |
| $B_1$ | Unity-gain bandwidth | $R_L = 2\ k\Omega$, $C_L = 100$ pF | 25°C | | 6 | | | 6 | | MHz |
| | Gain-bandwidth product | $R_L = 2\ k\Omega$, $C_L = 100$ pF, f = 100 kHz | 25°C | | 5.9 | | | 5.9 | | MHz |
| $B_{OM}$ | Maximum output-swing bandwidth | $V_{O(PP)} = 20$ V, $R_L = 2\ k\Omega$, $A_{VD} = 1$, $C_L = 100$ pF | 25°C | | 668 | | | 668 | | kHz |
| $\phi_m$ | Phase margin at unity gain | $R_L = 2\ k\Omega$, $C_L = 100$ pF | 25°C | | 58° | | | 58° | | |

## electrical characteristics at specified free-air temperature, $V_{CC}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2141I | | | TLE2141AI | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_O$ = 2.5 V,<br>$R_S$ = 50 Ω,<br>$V_{IC}$ = 2.5 V | 25°C | | 225 | 1400 | | 200 | 1000 | µV |
| | | | Full range | | | 1900 | | | 1500 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 1.7 | | | 1.7 | | µV/°C |
| $I_{IO}$ | Input offset current | | 25°C | | 8 | 100 | | 8 | 100 | nA |
| | | | Full range | | | 200 | | | 200 | |
| $I_{IB}$ | Input bias current | | 25°C | | − 0.8 | − 2 | | − 0.8 | − 2 | µA |
| | | | Full range | | | − 2.2 | | | − 2.2 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S$ = 50 Ω | 25°C | 0<br>to<br>3 | − 0.3<br>to<br>3.2 | | 0<br>to<br>3 | − 0.3<br>to<br>3.2 | | V |
| | | | Full range | 0<br>to<br>2.7 | − 0.3<br>to<br>2.9 | | 0<br>to<br>2.7 | − 0.3<br>to<br>2.9 | | |
| $V_{OH}$ | High-level output voltage | $I_{OH}$ = − 150 µA | 25°C | 3.9 | 4.1 | | 3.9 | 4.1 | | V |
| | | $I_{OH}$ = − 1.5 mA | | 3.8 | 4 | | 3.8 | 4 | | |
| | | $I_{OH}$ = − 15 mA | | 3.2 | 3.7 | | 3.2 | 3.7 | | |
| | | $I_{OH}$ = − 100 µA | Full range | 3.8 | | | 3.8 | | | |
| | | $I_{OH}$ = − 1 mA | | 3.7 | | | 3.7 | | | |
| | | $I_{OH}$ = − 10 mA | | 3.3 | | | 3.3 | | | |
| $V_{OL}$ | Low-level output voltage | $I_{OL}$ = 150 µA | 25°C | | 75 | 125 | | 75 | 125 | mV |
| | | $I_{OL}$ = 1.5 mA | | | 150 | 225 | | 150 | 225 | |
| | | $I_{OL}$ = 15 mA | | | 1.2 | 1.6 | | 1.2 | 1.6 | V |
| | | $I_{OL}$ = 100 µA | Full range | | | 175 | | | 175 | mV |
| | | $I_{OL}$ = 1 mA | | | | 225 | | | 225 | |
| | | $I_{OL}$ = 10 mA | | | | 1.4 | | | 1.4 | V |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_{CC}$ = ± 2.5 V, $R_L$ = 2 kΩ,<br>$V_O$ = 1 V to − 1.5 V | 25°C | 50 | 220 | | 50 | 220 | | V/mV |
| | | | Full range | 10 | | | 10 | | | |
| $r_i$ | Input resistance | | 25°C | | 70 | | | 70 | | MΩ |
| $c_i$ | Input capacitance | | 25°C | | 2.5 | | | 2.5 | | pF |
| $z_o$ | Open-loop output impedance | f = 1 MHz | 25°C | | 30 | | | 30 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC}$ = $V_{ICR}$ min,<br>$R_S$ = 50 Ω | 25°C | 85 | 118 | | 85 | 118 | | dB |
| | | | Full range | 80 | | | 80 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm}$ / $\Delta V_{IO}$) | $V_{CC\pm}$ = ± 2.5 V to ± 15 V,<br>$R_S$ = 50 Ω | 25°C | 90 | 106 | | 90 | 106 | | dB |
| | | | Full range | 85 | | | 85 | | | |
| $I_{CC}$ | Supply current | $V_O$ = 2.5 V, No Load,<br>$V_{IC}$ = 2.5 V | 25°C | | 3.4 | 4.4 | | 3.4 | 4.4 | mA |
| | | | Full range | | | 4.6 | | | 4.6 | |

†Full range is –40°C to 105°C.

## operating characteristics at specified free-air temperature, $V_{CC} = 5$ V

| PARAMETER | | TEST CONDITIONS | | $T_A$ | TLE2142I | | | TLE2141AI | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR + | Positive slew rate | $A_{VD} = -1$, $R_L = 2\ k\Omega^{\dagger}$, $C_L = 500$ pF | | 25°C | | 45 | | | 45 | | V/µs |
| SR − | Negative slew rate | | | | | 42 | | | 42 | | |
| | Settling time | $A_{VD} = -1$, 2.5-V Step | To 0.1% | 25°C | | 0.16 | | | 0.16 | | µs |
| | | | To 0.01% | | | 0.22 | | | 0.22 | | |
| $V_n$ | Equivalent input noise voltage | $R_S = 100\ \Omega$, $f = 10$ Hz | | 25°C | | 15 | | | 15 | | nV/√Hz |
| | | $R_S = 100\ \Omega$, $f = 1$ kHz | | | | 10.5 | | | 10.5 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | $f = 0.1$ Hz to 1 Hz | | 25°C | | 0.48 | | | 0.48 | | µV |
| | | $f = 0.1$ Hz to 10 Hz | | | | 0.51 | | | 0.51 | | |
| $I_n$ | Equivalent input noise current | $f = 10$ Hz | | 25°C | | 1.92 | | | 1.92 | | pA/√Hz |
| | | $f = 1$ kHz | | | | 0.5 | | | 0.5 | | |
| THD + N | Total harmonic distortion plus noise | $V_O = 1$ V to 3 V, $R_L = 2\ k\Omega^{\dagger}$, $A_{VD} = 2$, $f = 10$ kHz | | 25°C | | 0.0052 % | | | 0.0052 % | | |
| $B_1$ | Unity-gain bandwidth | $R_L = 2\ k\Omega^{\dagger}$, $C_L = 100$ pF | | 25°C | | 5.9 | | | 5.9 | | MHz |
| | Gain-bandwidth product | $R_L = 2\ k\Omega^{\dagger}$, $C_L = 100$ pF, $f = 100$ kHz | | 25°C | | 5.8 | | | 5.8 | | MHz |
| $B_{OM}$ | Maximum output-swing bandwidth | $R_L = 2\ k\Omega^{\dagger}$, $V_{O(PP)} = 2$ V, $A_{VD} = 1$, $C_L = 100$ pF | | 25°C | | 6.6 | | | 6.6 | | MHz |
| $\phi_m$ | Phase margin at unity-gain | $R_L = 2\ k\Omega^{\dagger}$, $C_L = 100$ pF | | 25°C | | 57° | | | 57° | | |

$^{\dagger}R_L$ terminates at 2.5 V.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| | PARAMETER | TEST CONDITIONS | $T_A$† | TLE2141I MIN | TLE2141I TYP | TLE2141I MAX | TLE2141AI MIN | TLE2141AI TYP | TLE2141AI MAX | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | $V_{IC} = 0$,<br>$R_S = 50\ \Omega$,<br>$V_O = 0$ | 25°C | | 200 | 900 | | 175 | 500 | μV |
| | | | Full range | | | 1500 | | | 1000 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 1.7 | | | 1.7 | | μV/°C |
| $I_{IO}$ | Input offset current | | 25°C | | 7 | 100 | | 7 | 100 | nA |
| | | | Full range | | | 200 | | | 200 | |
| $I_{IB}$ | Input bias current | | 25°C | | −0.7 | −1.5 | | −0.7 | −1.5 | μA |
| | | | Full range | | | −1.7 | | | −1.7 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | 25°C | −15<br>to<br>13 | −15.3<br>to<br>13.2 | | −15<br>to<br>13 | −15.3<br>to<br>13.2 | | V |
| | | | Full range | −15<br>to<br>12.7 | −15.3<br>to<br>12.9 | | −15<br>to<br>12.7 | −15.3<br>to<br>12.9 | | |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $I_O = -150\ \mu A$ | 25°C | 13.8 | 14.1 | | 13.8 | 14.1 | | V |
| | | $I_O = -1.5$ mA | | 13.7 | 14 | | 13.7 | 14 | | |
| | | $I_O = -15$ mA | | 13.1 | 13.7 | | 13.1 | 13.7 | | |
| | | $I_O = -100\ \mu A$ | Full range | 13.7 | | | 13.7 | | | |
| | | $I_O = -1$ mA | | 13.6 | | | 13.6 | | | |
| | | $I_O = -10$ mA | | 13.1 | | | 13.1 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | $I_O = 150\ \mu A$ | 25°C | −14.7 | −14.9 | | −14.7 | −14.9 | | V |
| | | $I_O = 1.5$ mA | | −14.5 | −14.8 | | −14.5 | −14.8 | | |
| | | $I_O = 15$ mA | | −13.4 | −13.8 | | −13.4 | −13.8 | | |
| | | $I_O = 100\ \mu A$ | Full range | −14.6 | | | −14.6 | | | |
| | | $I_O = 1$ mA | | −14.5 | | | −14.5 | | | |
| | | $I_O = 10$ mA | | −13.4 | | | −13.4 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = \pm 10$ V, $R_L = 2\ k\Omega$ | 25°C | 100 | 450 | | 100 | 450 | | V/mV |
| | | | Full range | 40 | | | 40 | | | |
| $r_i$ | Input resistance | | 25°C | | 65 | | | 65 | | MΩ |
| $c_i$ | Input capacitance | | 25°C | | 2.5 | | | 2.5 | | pF |
| $z_o$ | Open-loop output impedance | f = 1 MHz | 25°C | | 30 | | | 30 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min,<br>$R_S = 50\ \Omega$ | 25°C | 85 | 108 | | 85 | 108 | | dB |
| | | | Full range | 80 | | | 80 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 2.5$ V to $\pm 15$ V,<br>$R_S = 50\ \Omega$ | 25°C | 90 | 106 | | 90 | 106 | | dB |
| | | | Full range | 85 | | | 85 | | | |
| $I_{OS}$ | Short-circuit output current | $V_O = 0$, $V_{ID} = 1$ V | 25°C | −25 | −50 | | −25 | −50 | | mA |
| | | $V_O = 0$, $V_{ID} = -1$ V | | 20 | 31 | | 20 | 31 | | |
| $I_{CC}$ | Supply current | $V_O = 0$, No Load | 25°C | | 3.5 | 4.5 | | 3.5 | 4.5 | mA |
| | | | Full range | | | 4.7 | | | 4.7 | |

†Full range is –40C to 105°C.

## operating characteristics at specified free-air temperature, $V_{CC\pm}$ = ±15 V

| | PARAMETER | TEST CONDITIONS | $T_A$ | TLE2141I | | | TLE2141AI | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR + | Positive slew rate | $A_{VD}$ = −1, $R_L$ = 2 kΩ, $C_L$ = 500 pF | 25°C | 30 | 45 | | 30 | 45 | | V/μs |
| SR − | Negative slew rate | | 25°C | 30 | 42 | | 30 | 42 | | |
| | Settling time | $A_{VD}$ = −1, 10 V Step, To 0.1% | 25°C | | 0.34 | | | 0.34 | | μs |
| | | $A_{VD}$ = −1, 10 V Step, To 0.01% | | | 0.4 | | | 0.4 | | |
| $V_n$ | Equivalent input noise voltage | $R_S$ = 100 Ω, f = 10 Hz | 25°C | | 15 | | | 15 | | nV/√Hz |
| | | $R_S$ = 100 Ω, f = 1 kHz | | | 10.5 | | | 10.5 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz | 25°C | | 0.48 | | | 0.48 | | μV |
| | | f = 0.1 Hz to 10 Hz | | | 0.51 | | | 0.51 | | |
| $I_n$ | Equivalent input noise current | f = 10 Hz | 25°C | | 1.89 | | | 1.89 | | pA/√Hz |
| | | f = 1 kHz | | | 0.47 | | | 0.47 | | |
| THD + N | Total harmonic distortion plus noise | $V_{O(PP)}$ = 20 V, $R_L$ = 2 kΩ, $A_{VD}$ = 10, f = 10 kHz | 25°C | | 0.01% | | | 0.01% | | |
| $B_1$ | Unity-gain bandwidth | $R_L$ = 2 kΩ, $C_L$ = 100 pF | 25°C | | 6 | | | 6 | | MHz |
| | Gain-bandwidth product | $R_L$ = 2 kΩ, $C_L$ = 100 pF, f = 100 kHz | 25°C | | 5.9 | | | 5.9 | | MHz |
| $B_{OM}$ | Maximum output-swing bandwidth | $V_{O(PP)}$ = 20 V, $R_L$ = 2 kΩ, $A_{VD}$ = 1, $C_L$ = 100 pF | 25°C | | 668 | | | 668 | | kHz |
| $\phi_m$ | Phase margin at unity gain | $R_L$ = 2 kΩ, $C_L$ = 100 pF | 25°C | | 58° | | | 58° | | |

## electrical characteristics at specified free-air temperature, $V_{CC}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2141M | | | TLE2141AM | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_O$ = 2.5 V,<br>$R_S$ = 50 Ω,<br>$V_{IC}$ = 2.5 V | 25°C | | 225 | 1400 | | 200 | 1000 | μV |
| | | | Full range | | | 2100 | | | 1700 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 1.7 | | | 1.7 | | μV/°C |
| $I_{IO}$ | Input offset current | | 25°C | | 8 | 100 | | 8 | 100 | nA |
| | | | Full range | | | 250 | | | 250 | |
| $I_{IB}$ | Input bias current | | 25°C | | − 0.8 | − 2 | | − 0.8 | − 2 | μA |
| | | | Full range | | | − 2.3 | | | − 2.3 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S$ = 50 Ω | 25°C | 0<br>to<br>3 | − 0.3<br>to<br>3.2 | | 0<br>to<br>3 | − 0.3<br>to<br>3.2 | | V |
| | | | Full range | 0<br>to<br>2.7 | − 0.3<br>to<br>2.9 | | 0<br>to<br>2.7 | − 0.3<br>to<br>2.9 | | |
| $V_{OH}$ | High-level output voltage | $I_{OH}$ = − 150 μA | 25°C | 3.9 | 4.1 | | 3.9 | 4.1 | | V |
| | | $I_{OH}$ = − 1.5 mA | | 3.8 | 4 | | 3.8 | 4 | | |
| | | $I_{OH}$ = − 15 mA | | 3.2 | 3.7 | | 3.2 | 3.7 | | |
| | | $I_{OH}$ = − 100 μA | Full range | 3.75 | | | 3.75 | | | |
| | | $I_{OH}$ = − 1 mA | | 3.65 | | | 3.65 | | | |
| | | $I_{OH}$ = − 10 mA | | 3.25 | | | 3.25 | | | |
| $V_{OL}$ | Low-level output voltage | $I_{OL}$ = 150 μA | 25°C | | 75 | 125 | | 75 | 125 | mV |
| | | $I_{OL}$ = 1.5 mA | | | 150 | 225 | | 150 | 225 | |
| | | $I_{OL}$ = 15 mA | | | 1.2 | 1.4 | | 1.2 | 1.4 | V |
| | | $I_{OL}$ = 100 μA | Full range | | | 200 | | | 200 | mV |
| | | $I_{OL}$ = 1 mA | | | | 250 | | | 250 | |
| | | $I_{OL}$ = 10 mA | | | | 1.25 | | | 1.25 | V |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_{CC\pm}$ = ± 2.5 V, $R_L$ = 2kΩ,<br>$V_O$ = 1 V to − 1.5 V | 25° | 50 | 220 | | 50 | 220 | | V/mV |
| | | | Full range | 5 | | | 5 | | | |
| $r_i$ | Input resistance | | 25°C | | 70 | | | 70 | | MΩ |
| $c_i$ | Input capacitance | | 25°C | | 2.5 | | | 2.5 | | pF |
| $z_o$ | Open-loop output impedance | f = 1 MHz | 25°C | | 30 | | | 30 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC}$ = $V_{ICR}$ min,<br>$R_S$ = 50 Ω | 25°C | 85 | 118 | | 85 | 118 | | dB |
| | | | Full range | 80 | | | 80 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm}$ = ± 2.5 V to ± 15 V,<br>$R_S$ = 50 Ω | 25°C | 90 | 106 | | 90 | 106 | | dB |
| | | | Full range | 85 | | | 85 | | | |
| $I_{CC}$ | Supply current | $V_O$ = 2.5 V, No Load,<br>$V_{IC}$ = 2.5 V | 25°C | | 3.4 | 4.4 | | 3.4 | 4.4 | mA |
| | | | Full range | | | 4.6 | | | 4.6 | |

†Full range is –55°C to 125° C.

## operating characteristics, $V_{CC}$ = 5 V

| PARAMETER | | TEST CONDITIONS | | $T_A$ | TLE2141M | | | TLE2141AM | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR+ | Positive slew rate | $A_{VD}$ = −1, $R_L$ = 2 kΩ†,<br>$C_L$ = 500 pF | | 25°C | | 45 | | | 45 | | V/µs |
| SR− | Negative slew rate | | | | | 42 | | | 42 | | |
| | Settling time | $A_{VD}$ = −1,<br>2.5-V Step | To 0.1% | 25°C | | 0.16 | | | 0.16 | | µs |
| | | | To 0.01% | | | 0.22 | | | 0.22 | | |
| $V_n$ | Equivalent input noise voltage | $R_S$ = 100 Ω, f = 10 Hz | | 25°C | | 15 | | | 15 | | nV/√Hz |
| | | $R_S$ = 100 Ω, f = 1 kHz | | | | 10.5 | | | 10.5 | | |
| $V_{N(PP}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz | | 25°C | | 0.48 | | | 0.48 | | µV |
| | | f = 0.1 Hz to 10 Hz | | | | 0.51 | | | 0.51 | | |
| $I_n$ | Equivalent input noise current | f = 10 Hz | | 25°C | | 1.92 | | | 1.92 | | pA/√Hz |
| | | f = 1 kHz | | | | 0.5 | | | 0.5 | | |
| THD+N | Total harmonic distortion plus noise | $V_O$ = 1 V to 3 V, $R_L$ = 2 kΩ†,<br>$A_{VD}$ = 2, f = 10 kHz | | 25°C | | 0.0052% | | | 0.0052% | | |
| B1 | Unity-gain bandwidth | $R_L$ = 2 kΩ†, $C_L$ = 100 pF | | 25°C | | 5.9 | | | 5.9 | | MHz |
| | Gain-bandwidth product | $R_L$ = 2 kΩ†, $C_L$ = 100 pF,<br>f = 100 kHz | | 25°C | | 5.8 | | | 5.8 | | MHz |
| $B_{OM}$ | Maximum output-swing bandwidth | $R_L$ = 2 kΩ†, $V_{O(PP)}$ = 2 V,<br>$A_{VD}$ = 1 | | 25°C | | 6.6 | | | 6.6 | | MHz |
| $\phi_m$ | Phase margin at unity gain | $R_L$ = 2 kΩ†, $C_L$ = 100 pF | | 25°C | | 57° | | | 57° | | |

†RL terminates at 2.5 V.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2141M | | | TLE2141AM | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 200 | 900 | | 175 | 500 | µV |
| | | | Full range | | | 1700 | | | 1200 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 1.7 | | | 1.7 | | µV/°C |
| $I_{IO}$ | Input offset current | | 25°C | | 7 | 100 | | 7 | 100 | nA |
| | | | Full range | | | 250 | | | 250 | |
| $I_{IB}$ | Input bias current | | 25°C | | – 0.7 | – 1.5 | | – 0.7 | – 1.5 | µA |
| | | | Full range | | | – 1.8 | | | – 1.8 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | 25°C | – 15 to 13 | – 15.3 to 13.2 | | – 15 to 13 | – 15.3 to 13.2 | | V |
| | | | Full range | – 15 to 12.7 | – 15.3 to 12.9 | | – 15 to 12.7 | – 15.3 to 12.9 | | |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $I_O = -150\ \mu A$ | 25°C | 13.8 | 14.1 | | 13.8 | 14.1 | | V |
| | | $I_O = -1.5$ mA | | 13.7 | 14 | | 13.7 | 14 | | |
| | | $I_O = -15$ mA | | 13.1 | 13.7 | | 13.1 | 13.7 | | |
| | | $I_O = -100\ \mu A$ | Full range | 13.7 | | | 13.7 | | | |
| | | $I_O = -1$ mA | | 13.6 | | | 13.6 | | | |
| | | $I_O = -10$ mA | | 13.1 | | | 13.1 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | $I_O = 150\ \mu A$ | 25°C | – 14.7 | – 14.9 | | – 14.7 | – 14.9 | | V |
| | | $I_O = 1.5$ mA | | – 14.5 | – 14.8 | | – 14.5 | – 14.8 | | |
| | | $I_O = 15$ mA | | – 13.4 | – 13.8 | | – 13.4 | – 13.8 | | |
| | | $I_O = 100\ \mu A$ | Full range | – 14.6 | | | – 14.6 | | | |
| | | $I_O = 1$ mA | | – 14.5 | | | – 14.5 | | | |
| | | $I_O = 10$ mA | | – 13.4 | | | – 13.4 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = \pm 10$ V, $R_L = 2\ k\Omega$ | 25°C | 100 | 450 | | 100 | 450 | | V/mV |
| | | | Full range | 20 | | | 20 | | | |
| $r_i$ | Input resistance | | 25°C | | 65 | | | 65 | | MΩ |
| $c_i$ | Input capacitance | | 25°C | | 2.5 | | | 2.5 | | pF |
| $z_o$ | Open-loop output impedance | f = 1 MHz | 25°C | | 30 | | | 30 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 25°C | 85 | 108 | | 85 | 108 | | dB |
| | | | Full range | 80 | | | 80 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 2.5$ V to ± 15 V, $R_S = 50\ \Omega$ | 25°C | 90 | 106 | | 90 | 106 | | dB |
| | | | Full range | 85 | | | 85 | | | |
| $I_{OS}$ | Short-circuit output current | $V_O = 0$, $V_{ID} = 1$ V | 25°C | – 25 | – 50 | | – 25 | – 50 | | mA |
| | | $V_O = 0$, $V_{ID} = -1$ V | | 20 | 31 | | 20 | 31 | | |
| $I_{CC}$ | Supply current | $V_O = 0$, No Load, $V_{IC} = 2.5$ V | 25°C | | 3.5 | 4.5 | | 3.5 | 4.5 | mA |
| | | | Full range | | | 4.7 | | | 4.7 | |

† Full range is –55°C to 125°C.

## operating characteristics, $V_{CC\pm}$ = ±15 V

| | PARAMETER | TEST CONDITIONS | | $T_A$ | TLE2141M | | | TLE2141AM | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR + | Positive slew rate | $A_{VD}$ = −1, $R_L$ = 2 kΩ, $C_L$ = 100 pF | | 25°C | 30 | 45 | | 30 | 45 | | V/μs |
| SR − | Negative slew rate | | | 25°C | 30 | 42 | | 30 | 42 | | |
| | Settling time | $A_{VD}$ = −1, 10 V Step | To 0.1% | 25°C | | 0.34 | | | 0.34 | | μs |
| | | | To 0.01% | | | .4 | | | .4 | | |
| $V_n$ | Equivalent input noise voltage | $R_S$ = 100 Ω, f = 10 Hz | | 25°C | | 15 | | | 15 | | nV/√Hz |
| | | $R_S$ = 100 Ω, f = 1 kHz | | | | 10.5 | | | 10.5 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz | | 25°C | | 0.48 | | | 0.48 | | μV |
| | | f = 0.1 Hz to 10 Hz | | | | 0.51 | | | 0.51 | | |
| $I_n$ | Equivalent input noise current | f = 10 Hz | | 25°C | | 1.89 | | | 1.89 | | pA/√Hz |
| | | f = 1 kHz | | | | 0.47 | | | 0.47 | | |
| THD + N | Total harmonic distortion plus noise | $V_{O(PP)}$ = 20 V, $R_L$ = 2 kΩ, $A_{VD}$ = 10, f = 10 kHz | | 25°C | | 0.01 % | | | 0.01 % | | |
| $B_1$ | Unity-gain bandwidth | $R_L$ = 2 kΩ, $C_L$ = 100 pF | | 25°C | | 6 | | | 6 | | MHz |
| | Gain-bandwidth product | $R_L$ = 2 kΩ, $C_L$ = 100 pF, f = 100 kHz | | 25°C | | 5.9 | | | 5.9 | | MHz |
| $B_{OM}$ | Maximum output-swing bandwidth | $V_{O(PP)}$ = 20 V, $R_L$ = 2 kΩ, $A_{VD}$ = 1, $C_L$ = 100 pF | | 25°C | | 668 | | | 668 | | kHz |
| $\phi_m$ | Phase margin at unity gain | $R_L$ = 2 kΩ, $C_L$ = 100 pF | | 25°C | | 58° | | | 58° | | |

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V, $T_A = 25°C$ (unless otherwise noted)

| | PARAMETER | TEST CONDITIONS | TLE2141Y | | | UNIT |
|---|---|---|---|---|---|---|
| | | | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC} = 0$, $R_S = 50\ \Omega$, $V_O = 0$ | | 200 | 1000 | µV |
| $I_{IO}$ | Input offset current | | | 7 | 100 | nA |
| $I_{IB}$ | Input bias current | | | − 0.7 | − 1.5 | µA |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | − 15<br>to<br>13 | − 15.3<br>to<br>13.2 | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $I_O = -150$ µA | 13.8 | 14.1 | | V |
| | | $I_O = -1.5$ mA | 13.7 | 14 | | |
| | | $I_O = -15$ mA | 13.3 | 13.7 | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | $I_O = 150$ µA | −14.7 | −14.9 | | V |
| | | $I_O = 1.5$ mA | −14.5 | −14.8 | | |
| | | $I_O = 15$ mA | − 13.4 | − 13.8 | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = \pm 10$ V, $R_L = 2\ k\Omega$ | 100 | 450 | | V/mV |
| $r_i$ | Input resistance | | | 65 | | MΩ |
| $c_i$ | Input capacitance | | | 2.5 | | pF |
| $z_o$ | Open-loop output impedance | f = 1 MHz | | 30 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 80 | 108 | | dB |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 2.5$ V to ± 15 V, $R_S = 50\ \Omega$ | 85 | 106 | | dB |
| $I_{OS}$ | Short-circuit output current | $V_O = 0$, $V_{ID} = 1$ V | − 25 | − 50 | | mA |
| | | $V_O = 0$, $V_{ID} = -1$ V | 20 | 31 | | |
| $I_{CC}$ | Supply current | $V_O = 0$, No Load | | 3.5 | 4.5 | mA |

## TYPICAL CHARACTERISTICS

| TABLE OF GRAPHS | | | | FIGURE |
|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | | Distribution | 1 |
| $I_{IO}$ | Input offset current | | vs Temperature | 2 |
| $I_{IB}$ | Input bias current | | vs Temperature | 3 |
| | | | vs Common-mode voltage | 4 |
| $V_{OM+}$ | Maximum positive peak output voltage | | vs Supply voltage | 5 |
| | | | vs Temperature | 6 |
| | | | vs Output current | 7 |
| | | | vs Settling time | 9 |
| $V_{OM-}$ | Maximum negative peak output voltage | | vs Supply voltage | 5 |
| | | | vs Temperature | 6 |
| | | | vs Output current | 8 |
| | | | vs Settling time | 9 |
| $V_{O(PP)}$ | Maximum peak-to-peak output voltage swing | | vs Frequency | 10 |
| $V_{OH}$ | High-level output voltage | | vs Output current | 11 |
| $V_{OL}$ | Low-level output voltage | | vs Output current | 12 |
| $A_{VD}$ | Differential voltage amplification | | vs Temperature | 13 |
| | | | vs Frequency | 14 |
| $z_O$ | Closed loop output impedance | | vs Frequency | 15 |
| $I_{OS}$ | Short-circuit output current | | vs Temperature | 16 |
| CMRR | Common-mode rejection ratio | | vs Frequency | 17 |
| | | | vs Temperature | 18 |
| $k_{SVR}$ | Supply-voltage rejection ratio | | vs Frequency | 19 |
| | | | vs Temperature | 20 |
| $I_{CC}$ | Supply current | | vs Temperature | 21 |
| | | | vs Supply-voltage | 22 |
| $V_N$ | Noise voltage | | vs Frequency | 23 |
| $V_{NPP}$ | Noise voltage | | Over a 10-second period | 24 |
| $I_n$ | Equivalent input noise current | | vs Frequency | 25 |
| THD + N | Total harmonic distortion plus noise | | vs Frequency | 26 |
| SR | Slew rate | | vs Temperature | 27 |
| | | | vs Load capacitance | 28 |
| | Pulse response | Noninverting large-signal | vs Time | 29 |
| | | Inverting large-signal | vs Time | 30 |
| | | Small-signal | vs Time | 31 |
| $B_1$ | Unity-gain bandwidth | | vs Load capacitance | 32 |
| | Gain margin | | vs Load capacitance | 33 |
| $\phi_m$ | Phase margin | | vs Load capacitance | 34 |
| | Phase shift | | vs Frequency | 14 |

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†Data at high and low temperatures are applciable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS[†]

TLE2141
DISTRIBUTION OF
INPUT OFFSET VOLTAGE

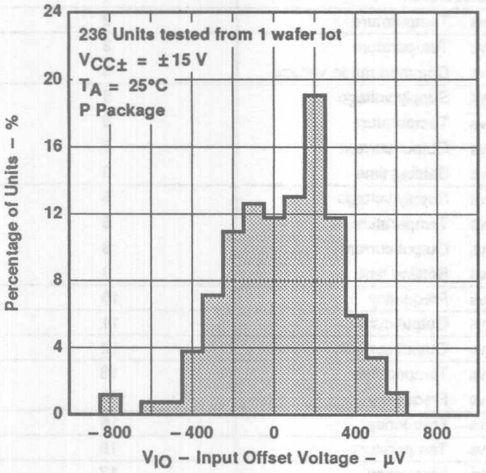

Figure 1

INPUT OFFSET CURRENT
vs
FREE-AIR TEMPERATURE

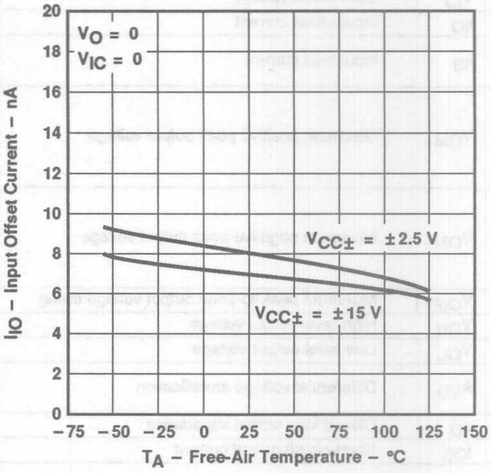

Figure 2

INPUT BIAS CURRENT
vs
FREE-AIR TEMPERATURE

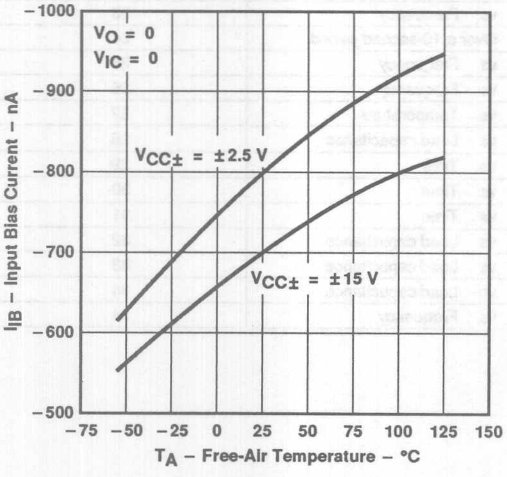

Figure 3

INPUT BIAS CURRENT
vs
COMMON-MODE INPUT VOLTAGE

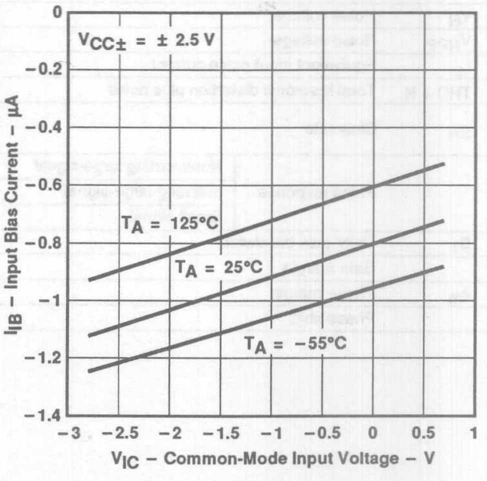

Figure 4

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[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

MAXIMUM PEAK OUTPUT VOLTAGE
vs
SUPPLY VOLTAGE

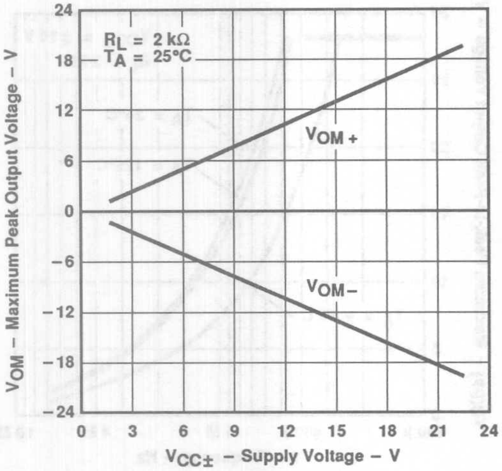

Figure 5

MAXIMUM PEAK OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE

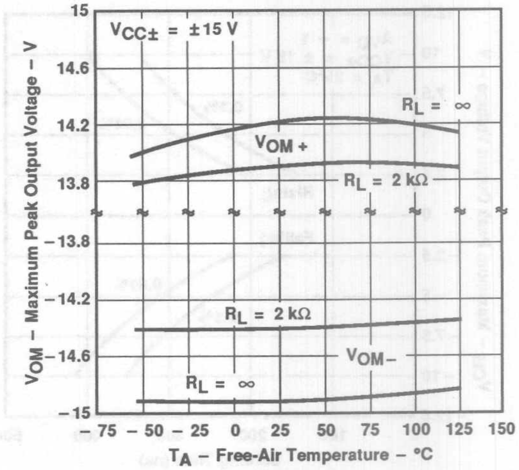

Figure 6

MAXIMUM POSITIVE PEAK
OUTPUT VOLTAGE
vs
OUTPUT CURRENT

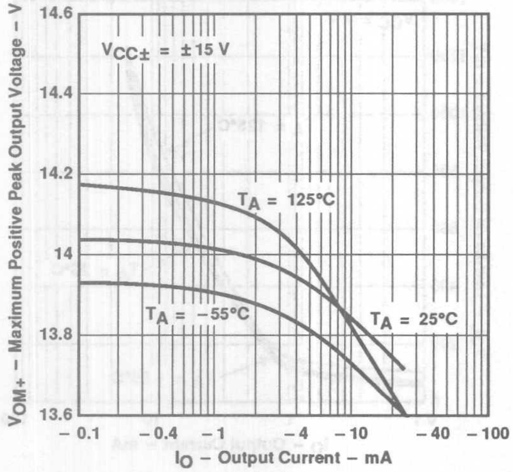

Figure 7

MAXIMUM NEGATIVE PEAK
OUTPUT VOLTAGE
vs
OUTPUT CURRENT

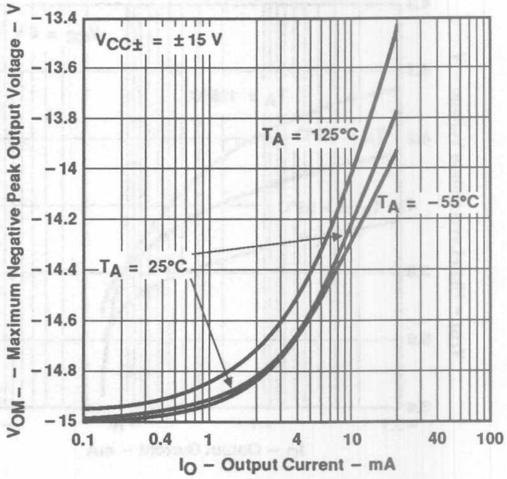

Figure 8

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†Data at high and low temperatures are applciable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS[†]

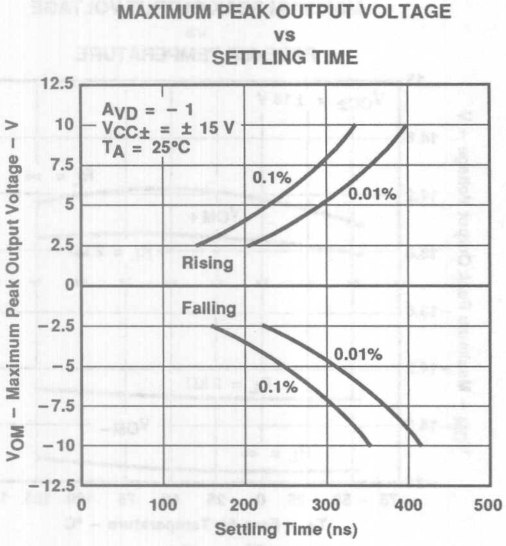
MAXIMUM PEAK OUTPUT VOLTAGE
vs
SETTLING TIME

Figure 9

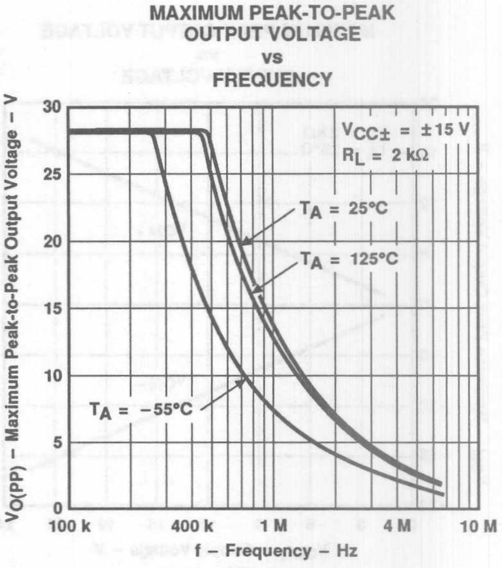
MAXIMUM PEAK-TO-PEAK
OUTPUT VOLTAGE
vs
FREQUENCY

Figure 10

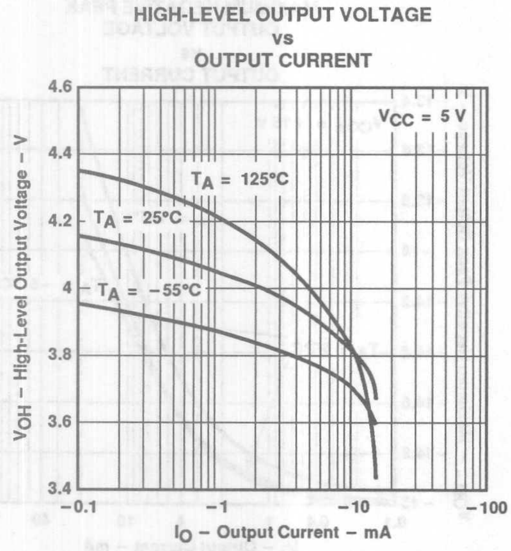
HIGH-LEVEL OUTPUT VOLTAGE
vs
OUTPUT CURRENT

Figure 11

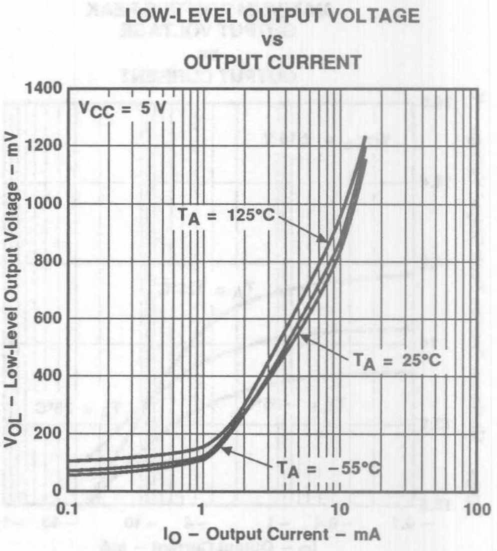
LOW-LEVEL OUTPUT VOLTAGE
vs
OUTPUT CURRENT

Figure 12

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[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

### LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION vs FREE-AIR TEMPERATURE

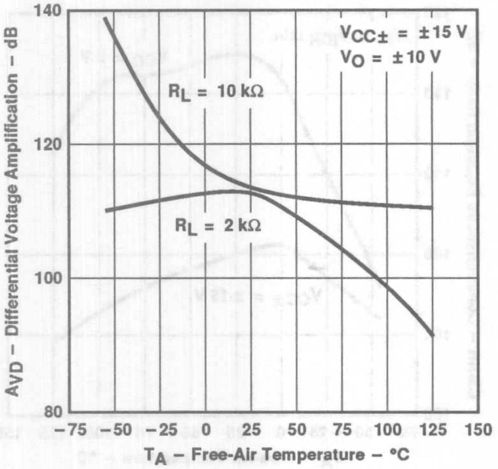

Figure 13

### LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT vs FREQUENCY

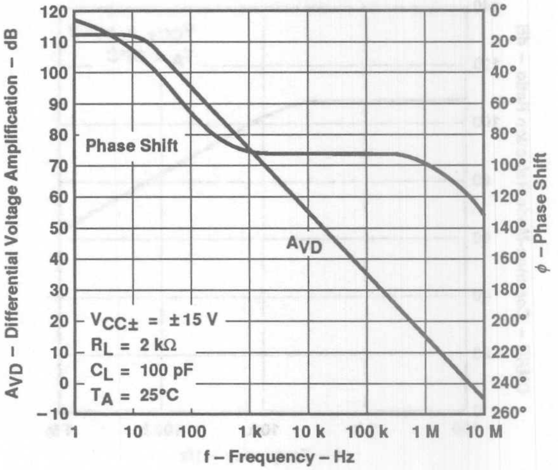

Figure 14

### CLOSED-LOOP OUTPUT IMPEDANCE vs FREQUENCY

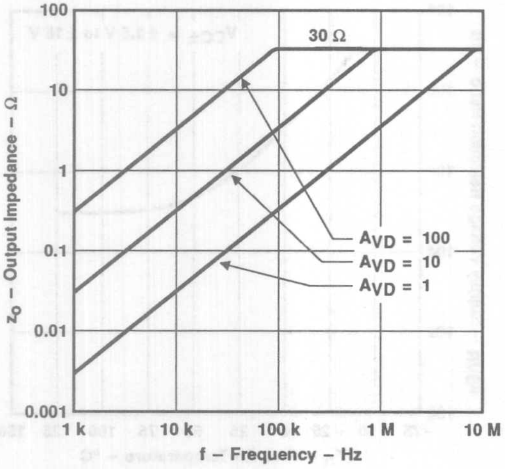

Figure 15

### SHORT-CIRCUIT OUTPUT CURRENT vs FREE-AIR TEMPERATURE

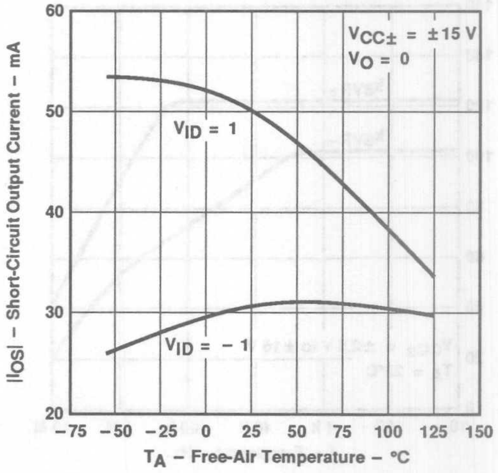

Figure 16

---

† Data at high and low temperatures are applciable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS[†]

COMMON-MODE REJECTION RATIO
vs
FREQUENCY

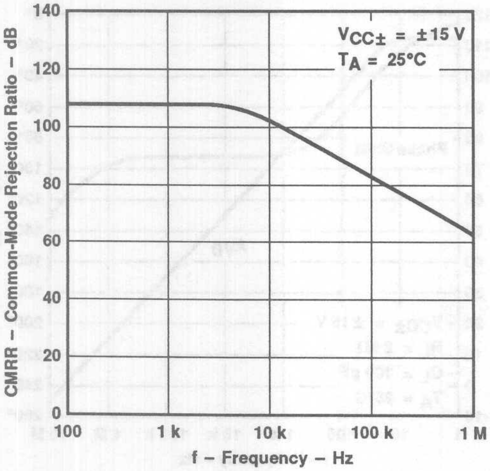

Figure 17

COMMON-MODE REJECTION RATIO
vs
FREE-AIR TEMPERATURE

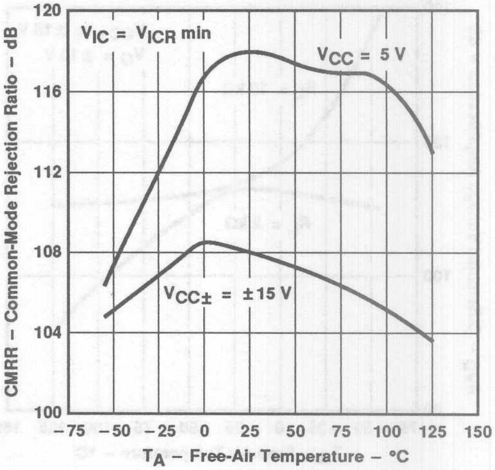

Figure 18

SUPPLY VOLTAGE REJECTION RATIO
vs
FREQUENCY

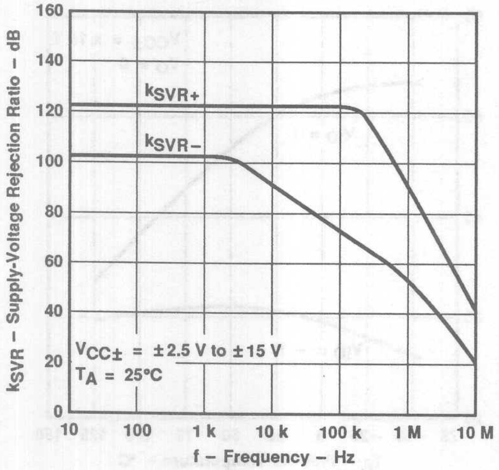

Figure 19

SUPPLY-VOLTAGE REJECTION RATIO
vs
FREE-AIR TEMPERATURE

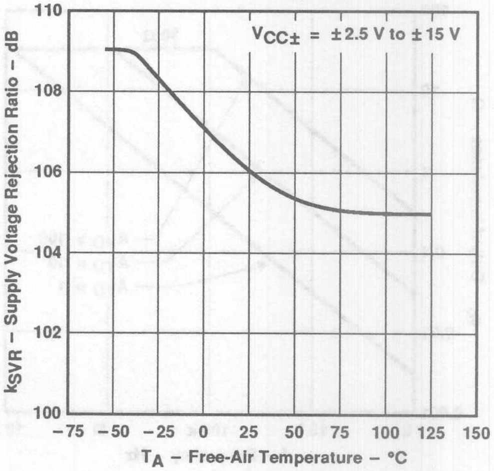

Figure 20

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[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS[†]

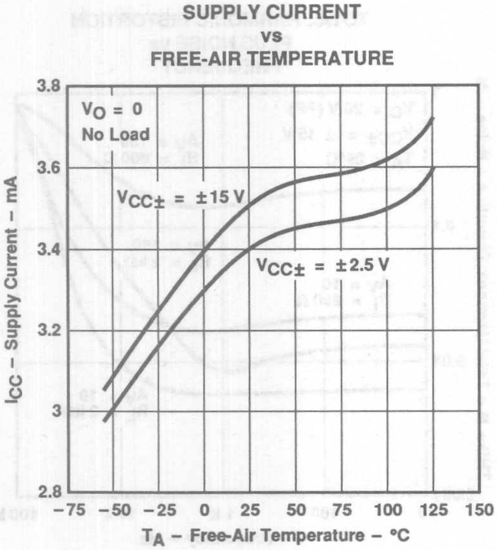

Figure 21

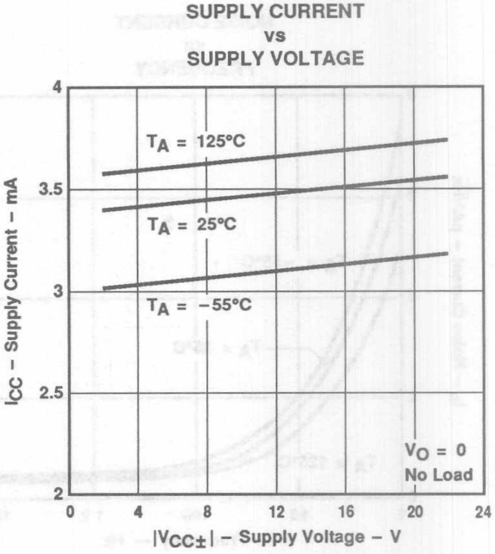

Figure 22

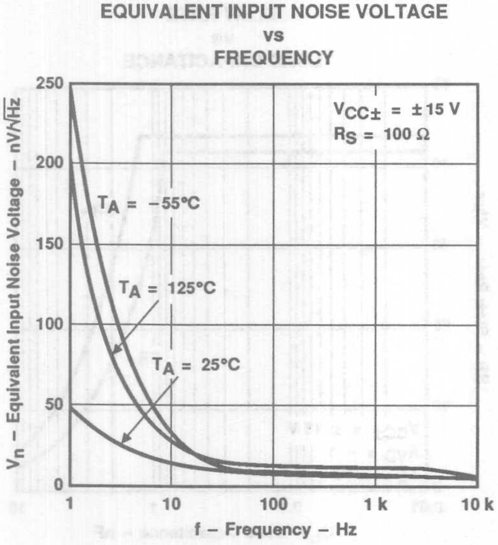

Figure 23

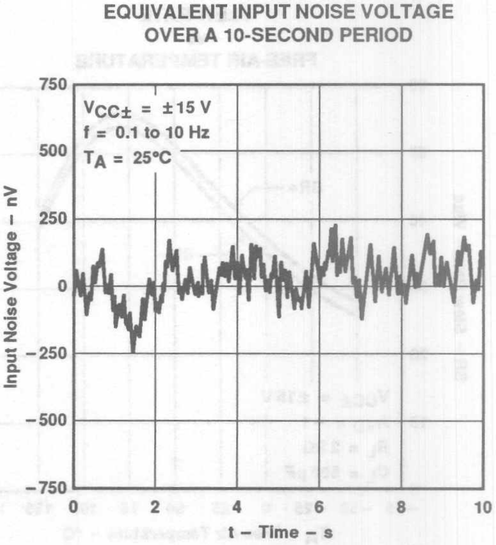

Figure 24

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[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

NOISE CURRENT
vs
FREQUENCY

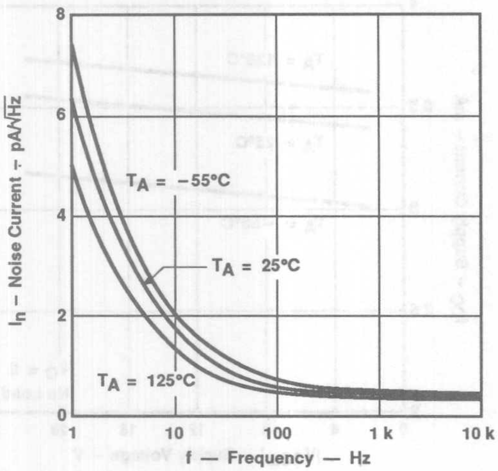

Figure 25

TOTAL HARMONIC DISTORTION
PLUS NOISE vs
FREQUENCY

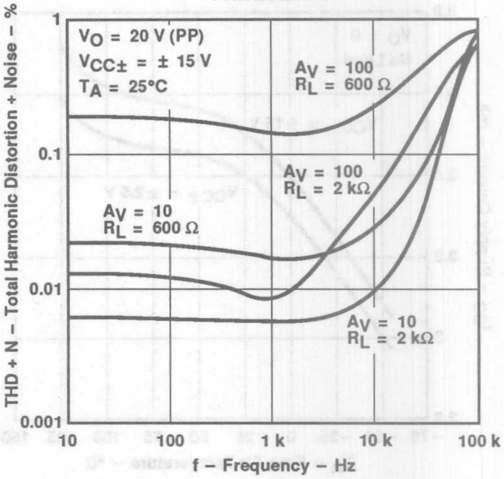

Figure 26

SLEW RATE
vs
FREE-AIR TEMPERATURE

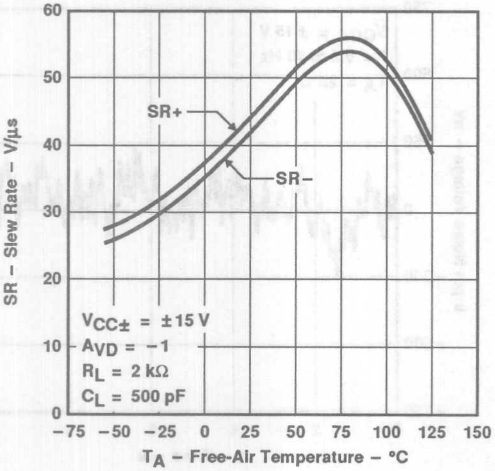

Figure 27

SLEW RATE
vs
LOAD CAPACITANCE

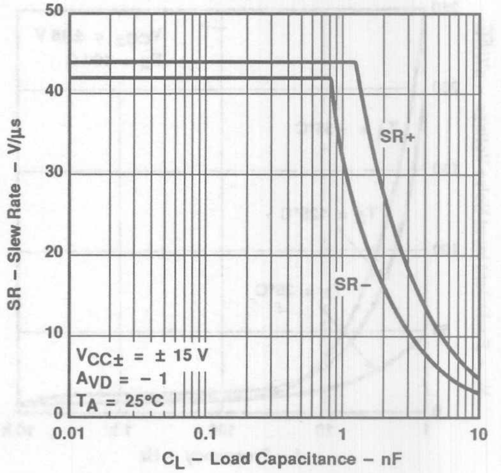

Figure 28

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†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

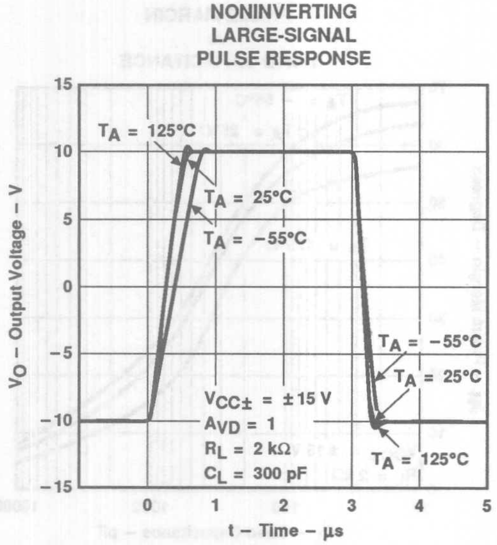

Figure 29

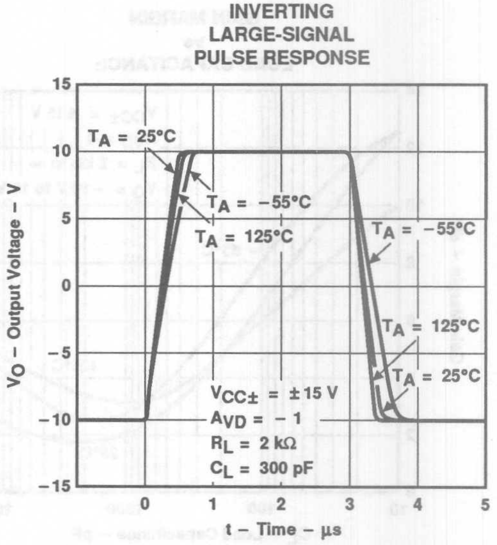

Figure 30

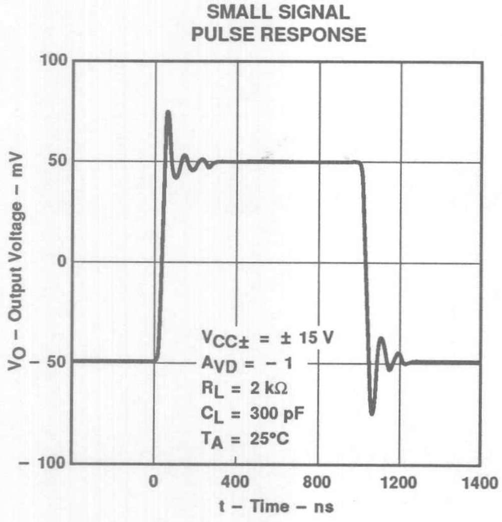

Figure 31

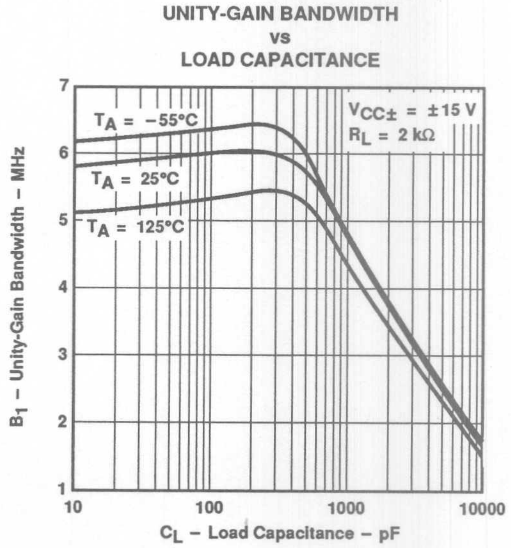

Figure 32

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†Data at high and low temperatures are applciable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

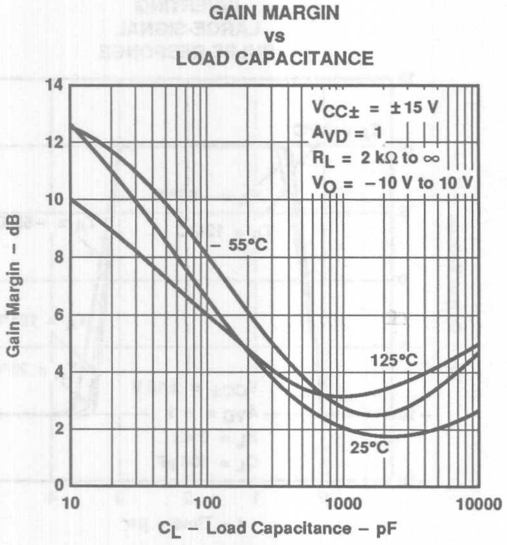

Figure 33

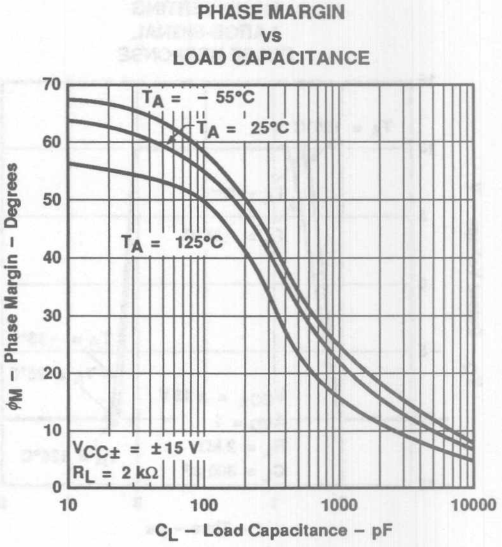

Figure 34

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†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

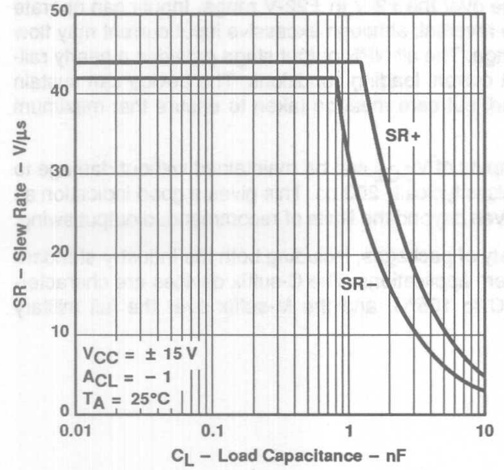
# TLE2142, TLE2142A
# EXCALIBUR LOW-NOISE HIGH-SPEED PRECISION DUAL OPERATIONAL AMPLIFIERS

D3667, MARCH 1991

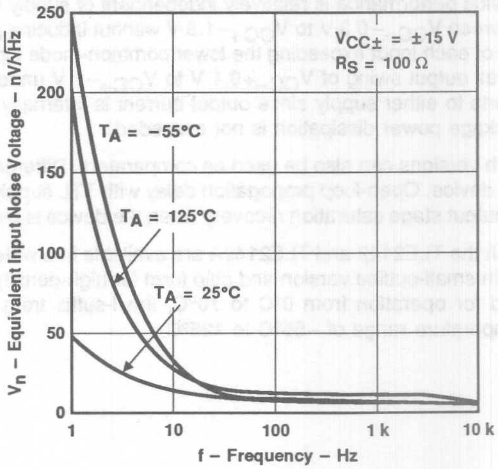
## available features

- **Low Noise:**
  **10 Hz . . . 15 nV/√Hz**
  **1 kHz . . . 10.5 nV/√Hz**
- **10,000-pF Load Capability**
- **20-mA Min Short-Circuit Output Current**
- **30-V/µs Min Slew Rate**
- **High Gain-Bandwidth Product . . . 5.9 MHz**
- **Low $V_{IO}$ . . . 750 µV Max at 25°C**
- **Single or Split Supply . . . 4 V to 44 V**
- **Fast Settling Time . . . 340 ns to 0.1%**
  **400 ns to 0.01%**
- **Saturation Recovery . . . 150 ns**
- **Large Output Swing . . . $V_{CC-}$ + 0.1 V to $V_{CC+}$ − 1 V**

**SLEW RATE vs LOAD CAPACITANCE**



**EQUIVALENT INPUT NOISE VOLTAGE vs FREQUENCY**



## description

The TLE2142 and TLE2142A are high-performance internally compensated operational amplifiers built using Texas Instruments complementary bipolar Excalibur process. The TLE2142A is a tighter offset-voltage grade of the TLE2142. Both are pin-compatible upgrades to standard industry products.

**AVAILABLE OPTIONS**

| $T_A$ | $V_{IO}$ max AT 25°C | PACKAGE | | | | | |
|---|---|---|---|---|---|---|---|
| | | SMALL-OUTLINE (D) | CHIP CARRIER (FK) | CERAMIC DIP (JG) | METAL CAN (L) | PLASTIC DIP (P) | CHIP FORM (Y) |
| 0°C to | 750 µV | TLE2142ACD | — | — | — | TLE2142ACP | TLE2142Y |
| 70°C | 1200 µV | TLE2142CD | — | — | — | TLE2142CP | |
| − 40°C to | 750 µV | TLE2142AID | — | — | — | TLE2142AIP | |
| 105°C | 1200 µV | TLE2142ID | — | — | — | TLE2142IP | |
| − 55°C to | 750 µV | TLE2142AMD | TLE2142AMFK | TLE2142AMJG | TLE2142AML | TLE2142AMP | |
| 125°C | 1200 µV | TLE2142MD | TLE2142MFK | TLE2142MJG | TLE2142ML | TLE2142MP | |

D packages are available taped and reeled. Add "R" suffix to device type, (e.g., TLE2142ACDR).

PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

TEXAS INSTRUMENTS
POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

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On products compliant to MIL-STD-883, Class B, all parameters are tested unless otherwise noted. On all other products, production processing does not necessarily include testing of all parameters.

## description (continued)

The design incorporates a patent-pending input stage that simultaneously achieves low audio band noise of 10.5 nV/$\sqrt{\text{Hz}}$ with a 6-Hz 1/f corner and symmetrical 40-V/µs slew rate typically with loads up to 800 pF. The resulting low distortion and high power-bandwidth are important in hi-fi audio applications. A fast settling time of 340 ns to 0.1% of a 10-V step with a 2-kΩ/100-pF load is useful in fast actuator/positioning drivers. Under similar test conditions, settling time to 0.01% is 400 ns.

The devices are stable with capacitive loads up to 10 nF, although the 6-MHz bandwidth decreases to 1.8 MHz at this high loading level. As such, the TLE2142 and TLE2142A are useful for low droop sample-and-holds and direct buffering of long cables, including 4-mA to 20-mA current loops.

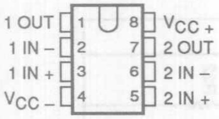
The special design also exhibits an improved insensitivity to inherent IC component mismatches as is evidenced by a 750-µV maximum offset voltage and 1.7-µV/°C typical drift. Minimum common-mode rejection ratio and supply-voltage rejection ratio are 85 dB and 90 dB, respectively.

Device performance is relatively independent of supply voltage over the ±2-V to ±22-V range. Inputs can operate between $V_{CC-}-0.3$ V to $V_{CC+}-1.8$ V without inducing phase reversal, although excessive input current may flow out of each input exceeding the lower common-mode input range. The all-NPN output stage provides a nearly rail-to-rail output swing of $V_{CC-}+0.1$ V to $V_{CC+}-1$ V under light current loading conditions. The device can sustain shorts to either supply since output current is internally limited, but care must be taken to ensure that maximum package power dissipation is not exceeded.

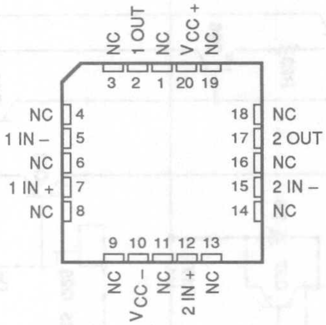
Both versions can also be used as comparators. Differential inputs of $V_{CC\pm}$ can be maintained without damage to the device. Open-loop propagation delay with TTL supply levels is typically 200 ns. This gives a good indication as to output stage saturation recovery when the device is over-driven beyond the limits of recommended output swing.

Both the TLE2142 and TLE2142A are available in a wide variety of packages, including both the industry-standard 8-pin small-outline version and chip form for high-density system applications. The C-suffix devices are characterized for operation from 0°C to 70°C, the I-suffix from −40°C to 105°C, and the M-suffix over the full military temperature range of −55°C to 125°C.

D, JG, OR P PACKAGE
(TOP VIEW)

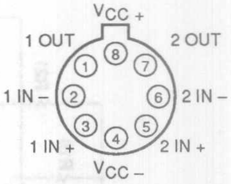


FK PACKAGE
(TOP VIEW)



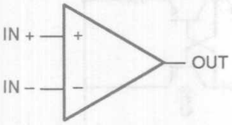
NC – No internal connection

L PACKAGE
(TOP VIEW)



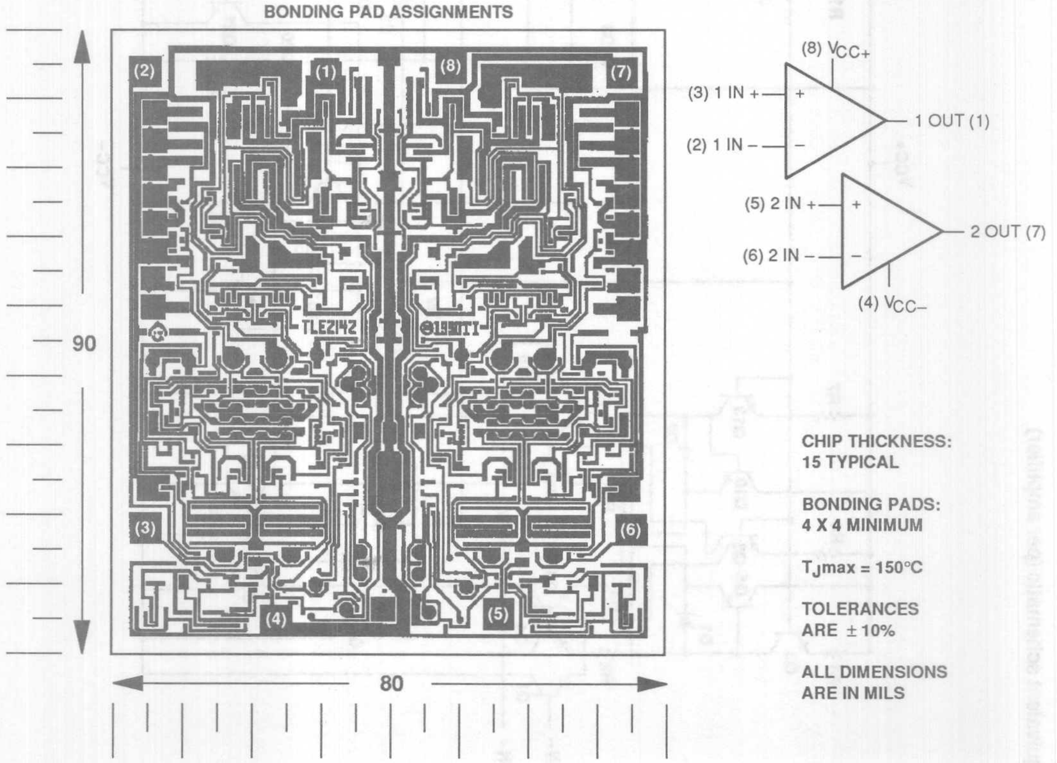
Pin 4 of the L package is in electrical contact with the case.

## symbol



## chip information

These chips, properly assembled, display characteristics similar to the TLE2142, (see electrical table on page 18). Thermal compression or ultrasonic bonding may be used on the doped aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



CHIP THICKNESS:
15 TYPICAL

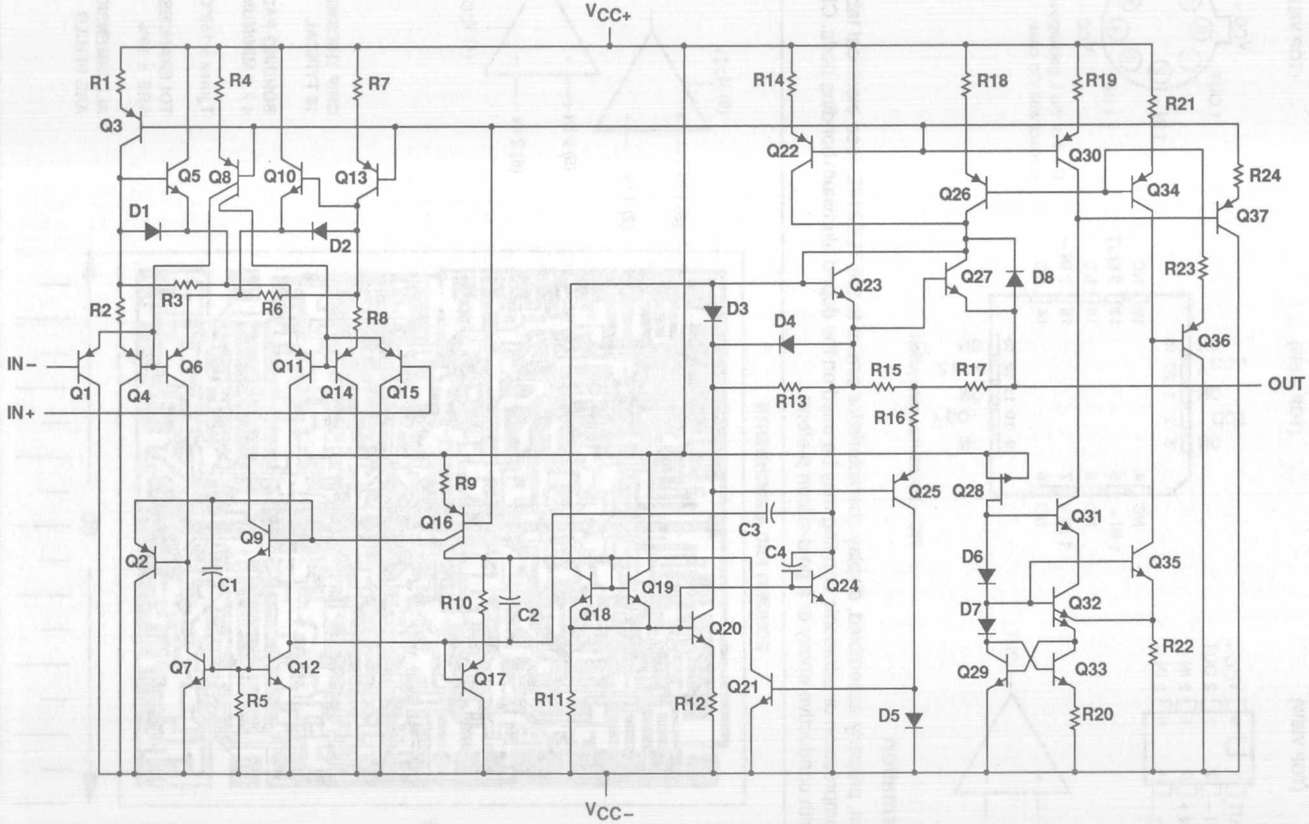
BONDING PADS:
4 X 4 MINIMUM

$T_J$max = 150°C

TOLERANCES
ARE ± 10%

ALL DIMENSIONS
ARE IN MILS

### equivalent schematic (per amplifier)



## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|---|
| Supply voltage, $V_{CC+}$ (see Note 1) | 22 V |
| Supply voltage, $V_{CC-}$ | −22 V |
| Differential input voltage (see Note 2) | $V_{CC+}$ to $V_{CC-}$ |
| Input voltage range, $V_I$ (any input) | $V_{CC+}$ to $V_{CC-} - 0.3$ V |
| Input current, $I_I$ (each input) | ±1 mA |
| Output current, $I_O$ | ±80 mA |
| Total current into $V_{CC+}$ terminal | 160 mA |
| Total current out of $V_{CC-}$ terminal | 160 mA |
| Duration of short-circuit current at (or below) 25°C (see Note 3) | unlimited |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range, $T_A$: C-suffix | 0°C to 70°C |
| I-suffix | −40°C to 105°C |
| M-suffix | −55°C to 125°C |
| Storage temperature range | −65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG or L package | 300°C |

NOTES:
1. All voltage values, except differential voltages, are with respect to the midpoint between $V_{CC+}$ and $V_{CC-}$.
2. Differential voltages are at the noninverting input with respect to the inverting input. Excessive current will flow if input is brought below $V_{CC-} - 0.3$ V.
3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \le 25°C$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25°C$ | $T_A = 70°C$ POWER RATING | $T_A = 105°C$ POWER RATING | $T_A = 125°C$ POWER RATING |
|---|---|---|---|---|---|
| D | 725 mW | 5.8 mW/°C | 464 mW | 261 mW | 145 mW |
| FK | 1375 mW | 11.0 mW/°C | 880 mW | 495 mW | 275 mW |
| JG | 1050 mW | 8.4 mW/°C | 672 mW | 378 mW | 210 mW |
| L | 650 mW | 5.2 mW/°C | 416 mW | 234 mW | 130 mW |
| P | 1000 mW | 8.0 mW/°C | 640 mW | 360 mW | 200 mW |

## recommended operating conditions

| | | C-SUFFIX | | I-SUFFIX | | M-SUFFIX | | UNIT |
|---|---|---|---|---|---|---|---|---|
| | | MIN | MAX | MIN | MAX | MIN | MAX | |
| Supply voltage, $V_{CC\pm}$ | | ± 2 | ± 22 | ± 2 | ± 22 | ± 2 | ± 22 | V |
| Common-mode input voltage, $V_{IC}$ | $V_{CC} = 5$ V | 0 | 2.9 | 0 | 2.7 | 0 | 2.7 | V |
| | $V_{CC\pm} = 15$ V | − 15 | 12.9 | − 15 | 12.7 | − 15 | 12.7 | |
| Operating free-air temperature, $T_A$ | | 0 | 70 | − 40 | 105 | − 55 | 125 | °C |

## electrical characteristics at specified free-air temperature, $V_{CC}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2142C | | | TLE2142AC | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_O$ = 2.5 V, $R_S$ = 50 Ω,<br>$V_{IC}$ = 2.5 V | 25°C | | 220 | 1900 | | 200 | 1500 | μV |
| | | | Full range | | | 2200 | | | 1800 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 1.7 | | | 1.7 | | μV/°C |
| $I_{IO}$ | Input offset current | | 25°C | | 8 | 100 | | 8 | 100 | nA |
| | | | Full range | | | 150 | | | 150 | |
| $I_{IB}$ | Input bias current | | 25°C | | − 0.8 | − 2 | | − 0.8 | − 2 | μA |
| | | | Full range | | | − 2.1 | | | − 2.1 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S$ = 50 Ω | 25°C | 0 to 3 | − 0.3 to 3.2 | | 0 to 3 | − 0.3 to 3.2 | | V |
| | | | Full range | 0 to 2.9 | | | 0 to 2.9 | | | |
| $V_{OH}$ | High-level output voltage | $I_{OH}$ = − 150 μA | 25°C | 3.9 | 4.1 | | 3.9 | 4.1 | | V |
| | | | Full range | 3.8 | | | 3.8 | | | |
| | | $I_{OH}$ = − 1.5 mA | 25°C | 3.8 | 4 | | 3.8 | 4 | | |
| | | | Full range | 3.7 | | | 3.7 | | | |
| | | $I_{OH}$ = − 15 mA | 25°C | 3.4 | 3.7 | | 3.4 | 3.7 | | |
| | | | Full range | 3.4 | | | 3.4 | | | |
| $V_{OL}$ | Low-level output voltage | $I_{OL}$ = 150 μA | 25°C | | 75 | 125 | | 75 | 125 | mV |
| | | | Full range | | | 150 | | | 150 | |
| | | $I_{OL}$ = 1.5 mA | 25°C | | 150 | 225 | | 150 | 225 | |
| | | | Full range | | | 250 | | | 250 | |
| | | $I_{OL}$ = 15 mA | 25°C | | 1.2 | 1.6 | | 1.2 | 1.6 | V |
| | | | Full range | | | 1.7 | | | 1.7 | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_{CC}$ = ± 2.5 V, $R_L$ = 2 kΩ,<br>$V_O$ = 1 V to − 1.5 V | 25°C | 50 | 220 | | 50 | 220 | | V/mV |
| | | | Full range | 25 | | | 25 | | | |
| $r_i$ | Input resistance | | 25°C | | 70 | | | 70 | | MΩ |
| $c_i$ | Input capacitance | | 25°C | | 2.5 | | | 2.5 | | pF |
| $z_o$ | Open-loop output impedance | f = 1 MHz | 25°C | | 30 | | | 30 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC}$ = $V_{ICR}$ min,<br>$R_S$ = 50 Ω | 25°C | 85 | 118 | | 85 | 118 | | dB |
| | | | Full range | 80 | | | 80 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm}$ = ± 2.5 V to ± 15 V,<br>$R_S$ = 50 Ω | 25°C | 90 | 106 | | 90 | 106 | | dB |
| | | | Full range | 85 | | | 85 | | | |
| $I_{CC}$ | Supply current | $V_O$ = 2.5 V, No Load,<br>$V_{IC}$ = 2.5 V | 25°C | | 6.6 | 8.8 | | 6.6 | 8.8 | mA |
| | | | Full range | | | 9.2 | | | 9.2 | |

† Full range is 0°C to 70°C.

## operating characteristics at specified free-air temperature, $V_{CC} = 5$ V

| | PARAMETER | TEST CONDITIONS | | $T_A$ | TLE2142C | | | TLE2142AC | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR + | Positive slew rate | $A_{VD} = -1$, $R_L = 2$ kΩ†, $C_L = 500$ pF | | 25°C | | 45 | | | 45 | | V/µs |
| SR – | Negative slew rate | | | | | 42 | | | 42 | | |
| | Settling time | $A_{VD} = -1$, 2.5-V Step | To 0.1% | 25°C | | 0.16 | | | 0.16 | | µs |
| | | | To 0.01% | | | 0.22 | | | 0.22 | | |
| $V_n$ | Equivalent input noise voltage | $R_S = 100$ Ω, f = 10 Hz | | 25°C | | 15 | | | 15 | | nV/√Hz |
| | | $R_S = 100$ Ω, f = 1 kHz | | | | 10.5 | | | 10.5 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz | | 25°C | | 0.48 | | | 0.48 | | µV |
| | | f = 0.1 Hz to 10 Hz | | | | 0.51 | | | 0.51 | | |
| $I_n$ | Equivalent input noise current | f = 10 Hz | | 25°C | | 1.92 | | | 1.92 | | pA/√Hz |
| | | f = 1 kHz | | | | 0.5 | | | 0.5 | | |
| THD + N | Total harmonic distortion plus noise | $V_O = 1$ V to 3 V, $R_L = 2$ kΩ†, $A_{VD} = 2$, f = 10 kHz | | 25°C | | 0.0052 % | | | 0.0052 % | | |
| $B_1$ | Unity-gain bandwidth | $R_L = 2$ kΩ†, $C_L = 100$ pF | | 25°C | | 5.9 | | | 5.9 | | MHz |
| | Gain-bandwidth product | $R_L = 2$ kΩ†, $C_L = 100$ pF, f = 100 kHz | | 25°C | | 5.8 | | | 5.8 | | MHz |
| $B_{OM}$ | Maximum output-swing bandwidth | $R_L = 2$ kΩ†, $V_{O(PP)} = 2$ V, $A_{VD} = 1$, $C_L = 100$ pF | | 25°C | | 5.9 | | | 5.9 | | MHz |
| $\phi_m$ | Phase margin at unity-gain | $R_L = 2$ kΩ†, $C_L = 100$ pF | | 25°C | | 57° | | | 57° | | |

† Note: $R_L$ terminates at 2.5 V.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$[†] | TLE2142C | | | TLE2142AC | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC} = 0$,<br>$R_S = 50\ \Omega$,<br>$V_O = 0$ | 25°C | | 290 | 1200 | | 275 | 750 | µV |
| | | | Full range | | | 1600 | | | 1200 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 1.7 | | | 1.7 | | µV/°C |
| $I_{IO}$ | Input offset current | | 25°C | | 7 | 100 | | 7 | 100 | nA |
| | | | Full range | | | 150 | | | 150 | |
| $I_{IB}$ | Input bias current | | 25°C | | −0.7 | −1.5 | | −0.7 | −1.5 | µA |
| | | | Full range | | | −1.6 | | | −1.6 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | 25°C | −15<br>to<br>13 | −15.3<br>to<br>13.2 | | −15<br>to<br>13 | −15.3<br>to<br>13.2 | | V |
| | | | Full range | −15<br>to<br>12.9 | −15.3<br>to<br>13.1 | | −15<br>to<br>12.9 | −15.3<br>to<br>13.1 | | |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $I_O = -150\ \mu A$ | 25°C | 13.8 | 14.1 | | 13.8 | 14.1 | | V |
| | | | Full range | 13.7 | | | 13.7 | | | |
| | | $I_O = -1.5$ mA | 25°C | 13.7 | 14 | | 13.7 | 14 | | |
| | | | Full range | 13.6 | | | 13.6 | | | |
| | | $I_O = -15$ mA | 25°C | 13.1 | 13.7 | | 13.1 | 13.7 | | |
| | | | Full range | 13 | | | 13 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | $I_O = 150\ \mu A$ | 25°C | −14.7 | −14.9 | | −14.7 | −14.9 | | V |
| | | | Full range | −14.6 | | | −14.6 | | | |
| | | $I_O = 1.5$ mA | 25°C | −14.5 | −14.8 | | −14.5 | −14.8 | | |
| | | | Full range | −14.4 | | | −14.4 | | | |
| | | $I_O = 15$ mA | 25°C | −13.4 | −13.8 | | −13.4 | −13.8 | | |
| | | | Full range | −13.3 | | | −13.3 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = \pm 10$ V | 25°C | 100 | 450 | | 100 | 450 | | V/mV |
| | | | Full range | 75 | | | 75 | | | |
| $r_i$ | Input resistance | $R_L = 2\ k\Omega$ | 25°C | | 65 | | | 65 | | MΩ |
| $c_i$ | Input capacitance | | 25°C | | 2.5 | | | 2.5 | | pF |
| $z_o$ | Open-loop output impedance | f = 1 MHz | 25°C | | 30 | | | 30 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min,<br>$R_S = 50\ \Omega$ | 25°C | 85 | 108 | | 85 | 108 | | dB |
| | | | Full range | 80 | | | 80 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 2.5$ V to ±15 V,<br>$R_S = 50\ \Omega$ | 25°C | 90 | 106 | | 90 | 106 | | dB |
| | | | Full range | 85 | | | 85 | | | |
| $I_{OS}$ | Short-circuit output current | $V_O = 0$, $V_{ID} = 1$ V | 25°C | −25 | −50 | | −25 | −50 | | mA |
| | | $V_O = 0$, $V_{ID} = -1$ V | | 20 | 31 | | 20 | 31 | | |
| $I_{CC}$ | Supply current | $V_O = 0$, No Load | 25°C | | 6.9 | 9 | | 6.9 | 9 | mA |
| | | | Full range | | | 9.4 | | | 9.4 | |

[†] Full range is 0°C to 70°C.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V

| | PARAMETER | TEST CONDITIONS | | $T_A$ | TLE2142C | | | TLE2142AC | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR + | Positive slew rate | $A_{VD} = -1$, $R_L = 2\ k\Omega$, $C_L = 500$ pF | | 25°C | 30 | 45 | | 30 | 45 | | V/μs |
| SR − | Negative slew rate | | | 25°C | 30 | 42 | | 30 | 42 | | |
| | Settling time | $A_{VD} = -1$, 10 V Step | To 0.1% | 25°C | | 0.34 | | | 0.34 | | μs |
| | | | To 0.01% | | | 0.4 | | | 0.4 | | |
| $V_n$ | Equivalent input noise voltage | $R_S = 100\ \Omega$, f = 10 Hz | | 25°C | | 15 | | | 15 | | nV/√Hz |
| | | $R_S = 100\ \Omega$, f = 1 kHz | | | | 10.5 | | | 10.5 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz | | 25°C | | 0.48 | | | 0.48 | | μV |
| | | f = 0.1 Hz to 10 Hz | | | | 0.51 | | | 0.51 | | |
| $I_n$ | Equivalent input noise current | f = 10 Hz | | 25°C | | 1.89 | | | 1.89 | | pA/√Hz |
| | | f = 1 kHz | | | | 0.47 | | | 0.47 | | |
| THD + N | Total harmonic distortion plus noise | $V_O = 20\ V_{PP}$, $R_L = 2\ k\Omega$, $A_{VD} = 10$, f = 10 kHz | | 25°C | | 0.01% | | | 0.01% | | |
| $B_1$ | Unity-gain bandwidth | $R_L = 2\ k\Omega$, $C_L = 100$ pF | | 25°C | | 6 | | | 6 | | MHz |
| | Gain-bandwidth product | $R_L = 2\ k\Omega$, $C_L = 100$ pF, f = 100 kHz | | 25°C | | 5.9 | | | 5.9 | | MHz |
| $B_{OM}$ | Maximum output-swing bandwidth | $V_{O(PP)} = 20$ V, $R_L = 2\ k\Omega$, $A_{VD} = 1$, $C_L = 100$ pF | | 25°C | | 668 | | | 668 | | kHz |
| $\phi_m$ | Phase margin at unity gain | $R_L = 2\ k\Omega$, $C_L = 100$ pF | | 25°C | | 58° | | | 58° | | |

## electrical characteristics at specified free-air temperature, $V_{CC}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2142I | | | TLE2142AI | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_O$ = 2.5 V,<br>$R_S$ = 50 Ω,<br>$V_{IC}$ = 2.5 V | 25°C | | 220 | 1900 | | 220 | 1500 | μV |
| | | | Full range | | | 2400 | | | 2000 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 1.7 | | | 1.7 | | μV/°C |
| $I_{IO}$ | Input offset current | | 25°C | | 8 | 100 | | 8 | 100 | nA |
| | | | Full range | | | 200 | | | 200 | |
| $I_{IB}$ | Input bias current | | 25°C | | −0.8 | −2 | | −0.8 | −2 | μA |
| | | | Full range | | | −2.2 | | | −2.2 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S$ = 50 Ω | 25°C | 0<br>to<br>3 | −0.3<br>to<br>3.2 | | 0<br>to<br>3 | −0.3<br>to<br>3.2 | | V |
| | | | Full range | 0<br>to<br>2.7 | −0.3<br>to<br>2.9 | | 0<br>to<br>2.7 | −0.3<br>to<br>2.9 | | |
| $V_{OH}$ | High-level output voltage | $I_{OH}$ = −150 μA | 25°C | 3.9 | 4.1 | | 3.9 | 4.1 | | V |
| | | $I_{OH}$ = −1.5 mA | | 3.8 | 4 | | 3.8 | 4 | | |
| | | $I_{OH}$ = −15 mA | | 3.4 | 3.7 | | 3.4 | 3.7 | | |
| | | $I_{OH}$ = 100 μA | Full range | 3.8 | | | 3.8 | | | |
| | | $I_{OH}$ = 1 mA | | 3.7 | | | 3.7 | | | |
| | | $I_{OH}$ = 10 mA | | 3.5 | | | 3.5 | | | |
| $V_{OL}$ | Low-level output voltage | $I_{OL}$ = 150 μA | 25°C | | 75 | 125 | | 75 | 125 | mV |
| | | $I_{OL}$ = 1.5 mA | | | 150 | 225 | | 150 | 225 | |
| | | $I_{OL}$ = 15 mA | | | 1.2 | 1.6 | | 1.2 | 1.6 | V |
| | | $I_{OL}$ = 100 μA | Full range | | | 175 | | | 175 | mV |
| | | $I_{OL}$ = 1 mA | | | | 225 | | | 225 | |
| | | $I_{OL}$ = 10 mA | | | | 1.4 | | | 1.4 | V |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_{CC}$ = ± 2.5 V, $R_L$ = 2 kΩ,<br>$V_O$ = 1 V to − 1.5 V | 25°C | 50 | 220 | | 50 | 220 | | V/mV |
| | | | Full range | 10 | | | 10 | | | |
| $r_i$ | Input resistance | | 25°C | | 70 | | | 70 | | MΩ |
| $c_i$ | Input capacitance | | 25°C | | 2.5 | | | 2.5 | | pF |
| $z_o$ | Open-loop output impedance | f = 1 MHz | 25°C | | 30 | | | 30 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC}$ = $V_{ICR}$ min,<br>$R_S$ = 50 Ω | 25°C | 85 | 118 | | 85 | 118 | | dB |
| | | | Full range | 80 | | | 80 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm}$ = ± 2.5 V to ± 15 V,<br>$R_S$ = 50 Ω | 25°C | 90 | 106 | | 90 | 106 | | dB |
| | | | Full range | 85 | | | 85 | | | |
| $I_{CC}$ | Supply current | $V_O$ = 2.5 V, No Load<br>$V_{IC}$ = 2.5 V | 25°C | | 6.6 | 8.8 | | 6.6 | 8.8 | mA |
| | | | Full range | | | 9.2 | | | 9.2 | |

† Full range is – 40°C to 105°C.

## operating characteristics at specified free-air temperature, $V_{CC}$ = 5 V

| | PARAMETER | TEST CONDITIONS | | $T_A$ | TLE2142I | | | TLE2142AI | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR + | Positive slew rate | $A_{VD}$ = − 1, $R_L$ = 2 kΩ†,<br>$C_L$ = 500 pF | | 25°C | | 45 | | | 45 | | V/μs |
| SR − | Negative slew rate | | | | | 42 | | | 42 | | |
| | Settling time | $A_{VD}$ = − 1,<br>2.5-V Step | To 0.1% | 25°C | | 0.16 | | | 0.16 | | μs |
| | | | To 0.01% | | | 0.22 | | | 0.22 | | |
| $V_n$ | Equivalent input noise voltage | $R_S$ = 100 Ω, f = 10 Hz | | 25°C | | 15 | | | 15 | | nV/√Hz |
| | | $R_S$ = 100 Ω, f = 1 kHz | | | | 10.5 | | | 10.5 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz | | 25°C | | 0.48 | | | 0.48 | | μV |
| | | f = 0.1 Hz to 10 Hz | | | | 0.51 | | | 0.51 | | |
| $I_n$ | Equivalent input noise current | f = 10 Hz | | 25°C | | 1.92 | | | 1.92 | | pA/√Hz |
| | | f = 1 kHz | | | | 0.5 | | | 0.5 | | |
| THD + N | Total harmonic distortion plus noise | $V_O$ = 1 V to 3 V, $R_L$ = 2 kΩ†,<br>$A_{VD}$ = 2, f = 10 kHz | | 25°C | | 0.0052 % | | | 0.0052 % | | |
| $B_1$ | Unity-gain bandwidth | $R_L$ = 2 kΩ†, $C_L$ = 100 pF | | 25°C | | 5.9 | | | 5.9 | | MHz |
| | Gain-bandwidth product | $R_L$ = 2 kΩ†, $C_L$ = 100 pF,<br>f = 100 kHz | | 25°C | | 5.8 | | | 5.8 | | MHz |
| $B_{OM}$ | Maximum output-swing bandwidth | $R_L$ = 2 kΩ†, $V_{O(PP)}$ = 2 V,<br>$A_{VD}$ = 1, $C_L$ = 100 pF | | 25°C | | 5.9 | | | 5.9 | | MHz |
| $\phi_m$ | Phase margin at unity-gain | $R_L$ = 2 kΩ†, $C_L$ = 100 pF | | 25°C | | 57° | | | 57° | | |

† Note: $R_L$ terminates at 2.5 V.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2142I | | | TLE2142AI | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC} = 0$, $R_S = 50\ \Omega$, $V_O = 0$ | 25°C | | 290 | 1200 | | 275 | 750 | μV |
| | | | Full range | | | 1800 | | | 1400 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 1.7 | | | 1.7 | | μV/°C |
| $I_{IO}$ | Input offset current | | 25°C | | 7 | 100 | | 7 | 100 | nA |
| | | | Full range | | | 200 | | | 200 | |
| $I_{IB}$ | Input bias current | | 25°C | | −0.7 | −1.5 | | −0.7 | −1.5 | μA |
| | | | Full range | | | −1.7 | | | −1.7 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | 25°C | −15 to 13 | −15.3 to 13.2 | | −15 to 13 | −15.3 to 13.2 | | V |
| | | | Full range | −15 to 12.7 | −15.3 to 12.9 | | −15 to 12.7 | −15.3 to 12.9 | | |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $I_O = -150$ μA, | 25°C | 13.8 | 14.1 | | 13.8 | 14.1 | | V |
| | | $I_O = -1.5$ mA, | | 13.7 | 14 | | 13.7 | 14 | | |
| | | $I_O = -15$ mA | | 13.1 | 13.7 | | 13.1 | 13.7 | | |
| | | $I_O = -100$ μA, | Full range | 13.7 | | | 13.7 | | | |
| | | $I_O = -1$ mA, | | 13.6 | | | 13.6 | | | |
| | | $I_O = -10$ mA | | 13.1 | | | 13.1 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | $I_O = 150$ μA, | 25°C | −14.7 | −14.9 | | −14.7 | −14.9 | | V |
| | | $I_O = 1.5$ mA, | | −14.5 | −14.8 | | −14.5 | −14.8 | | |
| | | $I_O = 15$ mA | | −13.4 | −13.8 | | −13.4 | −13.8 | | |
| | | $I_O = 100$ μA, | Full range | −14.6 | | | −14.6 | | | |
| | | $I_O = 1$ mA, | | −14.5 | | | −14.5 | | | |
| | | $I_O = 10$ mA | | −13.4 | | | −13.4 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = \pm 10$ V, $R_L = 2\ k\Omega$ | 25°C | 100 | 450 | | 100 | 450 | | V/mV |
| | | | Full range | 40 | | | 40 | | | |
| $r_i$ | Input resistance | | 25°C | | 65 | | | 65 | | MΩ |
| $c_i$ | Input capacitance | | 25°C | | 2.5 | | | 2.5 | | pF |
| $z_o$ | Open-loop output impedance | f = 1 MHz | 25°C | | 30 | | | 30 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min<br>$R_S = 50\ \Omega$ | 25°C | 85 | 108 | | 85 | 108 | | dB |
| | | | Full range | 80 | | | 80 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 2.5$ V to ± 15 V,<br>$R_S = 50\ \Omega$ | 25°C | 90 | 106 | | 90 | 106 | | dB |
| | | | Full range | 85 | | | 85 | | | |
| $I_{OS}$ | Short-circuit output current | $V_O = 0$, $V_{ID} = 1$ V | 25°C | −25 | −50 | | −25 | −50 | | mA |
| | | $V_O = 0$, $V_{ID} = -1$ V | | 20 | 31 | | 20 | 31 | | |
| $I_{CC}$ | Supply current | $V_O = 0$, No Load | 25°C | | 6.9 | 9 | | 6.9 | 9 | mA |
| | | | Full range | | | 9.4 | | | 9.4 | |

† Full range is −40°C to 105°C.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V

| | PARAMETER | TEST CONDITIONS | | $T_A$ | TLE2142I | | | TLE2142AI | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR + | Positive slew rate | $A_{VD} = -1$, $R_L = 2\ k\Omega$, | | 25°C | 30 | 45 | | 30 | 45 | | V/µs |
| SR − | Negative slew rate | $C_L = 500$ pF | | 25°C | 30 | 42 | | 30 | 42 | | |
| | Settling time | $A_{VD} = -1$,<br>10 V Step | To 0.1% | 25°C | | 0.34 | | | 0.34 | | µs |
| | | | To 0.01% | | | 0.4 | | | 0.4 | | |
| $V_n$ | Equivalent input noise voltage | $R_S = 100\ \Omega$, f = 10 Hz | | 25°C | | 15 | | | 15 | | nV/√Hz |
| | | $R_S = 100\ \Omega$, f = 1 kHz | | | | 10.5 | | | 10.5 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz | | 25°C | | 0.48 | | | 0.48 | | µV |
| | | f = 0.1 Hz to 10 Hz | | | | 0.51 | | | 0.51 | | |
| $I_n$ | Equivalent input noise current | f = 10 Hz | | 25°C | | 1.89 | | | 1.89 | | pA/√Hz |
| | | f = 1 kHz | | | | 0.47 | | | 0.47 | | |
| THD + N | Total harmonic distortion plus noise | $V_{O(PP)} = 20$ V, $R_L = 2\ k\Omega$,<br>$A_{VD} = 10$, f = 10 kHz | | 25°C | | 0.01% | | | 0.01% | | |
| $B_1$ | Unity-gain bandwidth | $R_L = 2\ k\Omega$, $C_L = 100$ pF | | 25°C | | 6 | | | 6 | | MHz |
| | Gain-bandwidth product | $R_L = 2\ k\Omega$, $C_L = 100$ pF,<br>f = 100 kHz | | 25°C | | 5.9 | | | 5.9 | | MHz |
| $B_{OM}$ | Maximum output-swing bandwidth | $V_{O(PP)} = 20$ V, $R_L = 2\ k\Omega$,<br>$A_{VD} = 1$, $C_L = 100$ pF | | 25°C | | 668 | | | 668 | | kHz |
| $\phi_m$ | Phase margin at unity gain | $R_L = 2\ k\Omega$, $C_L = 100$ pF | | 25°C | | 58° | | | 58° | | |

## electrical characteristics at specified free-air temperature, $V_{CC} = 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2142M | | | TLE2142AM | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_O = 2.5$ V,<br>$R_S = 50\ \Omega$,<br>$V_{IC} = 2.5$ V | 25°C | | 220 | 1900 | | 200 | 1500 | µV |
| | | | Full range | | | 2600 | | | 2200 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 1.7 | | | 1.7 | | µV/°C |
| $I_{IO}$ | Input offset current | | 25°C | | 8 | 100 | | 8 | 100 | nA |
| | | | Full range | | | 250 | | | 250 | |
| $I_{IB}$ | Input bias current | | 25°C | | −0.8 | −2 | | −0.8 | −2 | µA |
| | | | Full range | | | −2.3 | | | −2.3 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | 25°C | 0<br>to<br>3 | −0.3<br>to<br>3.2 | | 0<br>to<br>3 | −0.3<br>to<br>3.2 | | V |
| | | | Full range | 0<br>to<br>2.7 | −0.3<br>to<br>2.9 | | 0<br>to<br>2.7 | −0.3<br>to<br>2.9 | | |
| $V_{OH}$ | High-level output voltage | $I_{OH} = -150$ µA | 25°C | 3.9 | 4.1 | | 3.9 | 4.1 | | V |
| | | $I_{OH} = -1.5$ mA | | 3.8 | 4 | | 3.8 | 4 | | |
| | | $I_{OH} = -15$ mA | | 3.4 | 3.7 | | 3.4 | 3.7 | | |
| | | $I_{OH} = 100$ µA | Full range | 3.75 | | | 3.75 | | | |
| | | $I_{OH} = 1$ mA | | 3.65 | | | 3.65 | | | |
| | | $I_{OH} = 10$ mA | | 3.45 | | | 3.45 | | | |
| $V_{OL}$ | Low-level output voltage | $I_{OL} = 150$ µA | 25°C | | 75 | 125 | | 75 | 125 | mV |
| | | $I_{OL} = 1.5$ mA | | | 150 | 225 | | 150 | 225 | |
| | | $I_{OL} = 15$ mA | | | 1.2 | 1.6 | | 1.2 | 1.6 | V |
| | | $I_{OL} = 100$ µA | Full range | | | 200 | | | 200 | mV |
| | | $I_{OL} = 1$ mA | | | | 250 | | | 250 | |
| | | $I_{OL} = 10$ mA | | | | 1.45 | | | 1.45 | V |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_{CC} = \pm 2.5$ V, $R_L = 2$ kΩ,<br>$V_O = 1$ V to $-1.5$ V | 25° | 50 | 220 | | 50 | 220 | | V/mV |
| | | | Full range | 5 | | | 5 | | | |
| $r_i$ | Input resistance | | 25°C | | 70 | | | 70 | | MΩ |
| $c_i$ | Input capacitance | | 25°C | | 2.5 | | | 2.5 | | pF |
| $z_o$ | Open-loop output impedance | f = 1 MHz | 25°C | | 30 | | | 30 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min,<br>$R_S = 50\ \Omega$ | 25°C | 85 | 118 | | 85 | 118 | | dB |
| | | | Full range | 80 | | | 80 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 2.5$ V to $\pm 15$ V,<br>$R_S = 50\ \Omega$ | 25°C | 90 | 106 | | 90 | 106 | | dB |
| | | | Full range | 85 | | | 85 | | | |
| $I_{CC}$ | Supply current | $V_O = 2.5$ V, No Load<br>$V_{IC} = 2.5$ V | 25°C | | 6.6 | 8.8 | | 6.6 | 8.8 | mA |
| | | | Full range | | | 9.2 | | | 9.2 | |

† Full range is −55°C to 125°C.

## operating characteristics, $V_{CC}$ = 5 V, $T_A$ = 25°C (unless otherwise noted)

|  | PARAMETER | TEST CONDITIONS |  | $T_A$ | TLE2142M |  |  | TLE2142AM |  |  | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | MIN | TYP | MAX | MIN | TYP | MAX |  |
| SR + | Positive slew rate | $A_{VD}$ = − 1, $R_L$ = 2 kΩ,† |  | 25°C |  | 45 |  |  | 45 |  | V/µs |
| SR − | Negative slew rate | $C_L$ = 500 pF |  |  |  | 42 |  |  | 42 |  |  |
|  | Settling time | $A_{VD}$ = − 1,<br>2.5-V Step | To 0.1% | 25°C |  | 0.16 |  |  | 0.16 |  | µs |
|  |  |  | To 0.01% |  |  | 0.22 |  |  | 0.22 |  |  |
| $V_n$ | Equivalent input noise voltage | $R_S$ = 100 Ω, f = 10 Hz |  | 25°C |  | 15 |  |  | 15 |  | nV/√Hz |
|  |  | $R_S$ = 100 Ω, f = 1 kHz |  |  |  | 10.5 |  |  | 10.5 |  |  |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz |  | 25°C |  | 0.48 |  |  | 0.48 |  | µV |
|  |  | f = 0.1 Hz to 10 Hz |  |  |  | 0.51 |  |  | 0.51 |  |  |
| $I_n$ | Equivalent input noise current | f = 10 Hz |  | 25°C |  | 1.92 |  |  | 1.92 |  | pA/√Hz |
|  |  | f = 1 kHz |  |  |  | 0.5 |  |  | 0.5 |  |  |
| THD + N | Total harmonic distortion plus noise | $V_O$ = 1 V to 3 V, $R_L$ = 2 kΩ†,<br>$A_{VD}$ = 2, f = 10 kHz |  | 25°C |  | 0.0052% |  |  | 0.0052% |  |  |
| $B_1$ | Unity-gain bandwidth | $R_L$ = 2 kΩ†, $C_L$ = 100 pF |  | 25°C |  | 5.9 |  |  | 5.9 |  | MHz |
|  | Gain-bandwidth product | $R_L$ = 2 kΩ†, $C_L$ = 100 pF,<br>f = 100 kHz |  | 25°C |  | 5.8 |  |  | 5.8 |  | MHz |
| $B_{OM}$ | Maximum output-swing bandwidth | $R_L$ = 2 kΩ†, $V_{O(PP)}$ = 2 V,<br>$A_{VD}$ = 1 |  | 25°C |  | 5.9 |  |  | 5.9 |  | MHz |
| $\phi_m$ | Phase margin | $R_L$ = 2 kΩ†, $C_L$ = 100 pF |  |  |  | 57° |  |  | 57° |  |  |

† $R_L$ terminates at 2.5 V.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLE2142M MIN | TLE2142M TYP | TLE2142M MAX | TLE2142AM MIN | TLE2142AM TYP | TLE2142AM MAX | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | $V_{IC} = 0$, $R_S = 50\ \Omega$, | 25°C | | 290 | 1200 | | 275 | 750 | μV |
| | | | Full range | | | 2000 | | | 1600 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | Full range | | 1.7 | | | 1.7 | | μV/°C |
| $I_{IO}$ | Input offset current | | 25°C | | 7 | 100 | | 7 | 100 | nA |
| | | | Full range | | | 250 | | | 250 | |
| $I_{IB}$ | Input bias current | | 25°C | | – 0.7 | – 1.5 | | – 0.7 | – 1.5 | μA |
| | | | Full range | | | – 1.8 | | | – 1.8 | |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | 25°C | – 15 to 13 | – 15.3 to 13.2 | | – 15 to 13 | – 15.3 to 13.2 | | V |
| | | | Full range | – 15 to 12.7 | – 15.3 to 12.9 | | – 15 to 12.7 | – 15.3 to 12.9 | | |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $I_O = -150\ \mu A$ | 25°C | 13.8 | 14.1 | | 13.8 | 14.1 | | V |
| | | $I_O = -1.5$ mA | | 13.7 | 14 | | 13.7 | 14 | | |
| | | $I_O = -15$ mA | | 13.1 | 13.7 | | 13.1 | 13.7 | | |
| | | $I_O = -100\ \mu A$ | Full range | 13.7 | | | 13.7 | | | |
| | | $I_O = -1$ mA | | 13.6 | | | 13.6 | | | |
| | | $I_O = -10$ mA | | 13.1 | | | 13.1 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | $I_O = 150\ \mu A$ | 25°C | – 14.7 | – 14.9 | | – 14.7 | – 14.9 | | V |
| | | $I_O = 1.5$ mA | | – 14.5 | – 14.8 | | – 14.5 | – 14.8 | | |
| | | $I_O = 15$ mA | | – 13.4 | – 13.8 | | – 13.4 | – 13.8 | | |
| | | $I_O = 100\ \mu A$ | Full range | – 14.6 | | | – 14.6 | | | |
| | | $I_O = 1$ mA | | – 14.5 | | | – 14.5 | | | |
| | | $I_O = 10$ mA | | – 13.4 | | | – 13.4 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = \pm 10$ V, $R_L = 2\ k\Omega$ | 25°C | 100 | 450 | | 100 | 450 | | V/mV |
| | | | Full range | 20 | | | 20 | | | |
| $r_i$ | Input resistance | | 25°C | | 65 | | | 65 | | MΩ |
| $c_i$ | Input capacitance | | 25°C | | 2.5 | | | 2.5 | | pF |
| $z_o$ | Open-loop output impedance | f = 1 MHz | 25°C | | 30 | | | 30 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min,<br>$R_S = 50\ \Omega$ | 25°C | 85 | 108 | | 85 | 108 | | dB |
| | | | Full range | 80 | | | 80 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 2.5$ V to ± 15 V,<br>$R_S = 50\ \Omega$ | 25°C | 90 | 106 | | 90 | 106 | | dB |
| | | | Full range | 85 | | | 85 | | | |
| $I_{OS}$ | Short-circuit output current | $V_O = 0$, $V_{ID} = 1$ V | 25°C | – 25 | – 50 | | – 25 | – 50 | | mA |
| | | $V_O = 0$, $V_{ID} = -1$ V | | 20 | 31 | | 20 | 31 | | |
| $I_{CC}$ | Supply current | $V_O = 0$, No Load,<br>$V_{IC} = 2.5$ V | 25°C | | 6.9 | 9 | | 6.9 | 9 | mA |
| | | | Full range | | | 9.4 | | | 9.4 | |

† Full range is –55°C to 125°C.

## operating characteristics, $V_{CC\pm} = \pm 15$ V, $T_A = 25°C$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$ | TLE2142M | | | TLE2142AM | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR + | Positive slew rate | $R_L = 2\ k\Omega$, $A_{VD} = -1$,<br>$C_L = 100$ pF | | 25°C | 30 | 45 | | 30 | 45 | | V/μs |
| SR − | Negative slew rate | | | 25°C | 30 | 42 | | 30 | 42 | | |
| | Settling time | $A_{VD} = -1$,<br>10 V Step | To 0.1% | 25°C | | 0.34 | | | 0.34 | | μs |
| | | | To 0.01% | | | .4 | | | .4 | | |
| $V_n$ | Equivalent input noise voltage | $R_S = 100\ \Omega$, f = 10 Hz | | 25°C | | 15 | | | 15 | | nV/√Hz |
| | | $R_S = 100\ \Omega$, f = 1 kHz | | | | 10.5 | | | 10.5 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz | | 25°C | | 0.48 | | | 0.48 | | μV |
| | | f = 0.1 Hz to 10 Hz | | | | 0.51 | | | 0.51 | | |
| $I_n$ | Equivalent input noise current | f = 10 Hz | | 25°C | | 1.89 | | | 1.89 | | pA/√Hz |
| | | f = 1 kHz | | | | 0.47 | | | 0.47 | | |
| THD + N | Total harmonic distortion plus noise | $V_{O(PP)} = 20$ V, $R_L = 2\ k\Omega$,<br>$A_{VD} = 10$, f = 10 kHz | | 25°C | | 0.01 % | | | 0.01 % | | |
| $B_1$ | Unity-gain bandwidth | $R_L = 2\ k\Omega$, $C_L = 100$ pF | | 25°C | | 6 | | | 6 | | MHz |
| | Gain-bandwidth product | $R_L = 2\ k\Omega$, $C_L = 100$ pF,<br>f = 100 kHz | | 25°C | | 5.9 | | | 5.9 | | MHz |
| $B_{OM}$ | Maximum output-swing bandwidth | $V_{O(PP)} = 20$ V, $R_L = 2\ k\Omega$,<br>$A_{VD} = 1$, $C_L = 100$ pF | | 25°C | | 668 | | | 668 | | kHz |
| $\phi_m$ | Phase margin at unity gain | $R_L = 2\ k\Omega$, $C_L = 100$ pF | | 25°C | | 58° | | | 58° | | |

# TLE2142Y
# EXCALIBUR LOW-NOISE HIGH-SPEED PRECISION DUAL OPERATIONAL AMPLIFIERS

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V, $T_A = 25°C$

| PARAMETER | | TEST CONDITIONS | | TLE2142YC | | | UNIT |
|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC} = 0$, $R_S = 50\ \Omega$, $V_O = 0$ | | | 150 | 875 | μV |
| $I_{IO}$ | Input offset current | | | | 7 | 100 | nA |
| $I_{IB}$ | Input bias current | | | | − 0.7 | − 1.5 | μA |
| $V_{ICR}$ | Common-mode input voltage range | $R_S = 50\ \Omega$ | | − 15<br>to<br>13 | − 15.3<br>to<br>13.2 | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $I_O = -150\ \mu A$ | | 13.8 | 14.1 | | V |
| | | $I_O = -1.5$ mA | | 13.7 | 14 | | |
| | | $I_O = -15$ mA | | 13.3 | 13.7 | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | $I_O = 150\ \mu A$ | | −14.7 | −14.9 | | V |
| | | $I_O = 1.5$ mA | | −14.5 | −14.8 | | |
| | | $I_O = 15$ mA | | − 13.4 | − 13.8 | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O = \pm 10$ V, $R_L = 2\ k\Omega$ | | 100 | 450 | | V/mV |
| $r_i$ | Input resistance | | | | 65 | | MΩ |
| $c_i$ | Input capacitance | | | | 2.5 | | pF |
| $z_o$ | Open-loop output impedance | f = 1 MHz | | | 30 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | | 80 | 108 | | dB |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 2.5$ V to $\pm 15$ V, $R_S = 50\ \Omega$ | | 85 | 106 | | dB |
| $I_{OS}$ | Short-circuit output current | $V_O = 0$ | $V_{ID} = 1$ V | − 25 | − 50 | | mA |
| | | | $V_{ID} = -1$ V | 20 | 31 | | |
| $I_{CC}$ | Supply current | $V_O = 0$, No Load | | | 6.9 | 9.0 | mA |

## TYPICAL CHARACTERISTICS

| | TABLE OF GRAPHS | | | FIGURE |
|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | | Distribution | 1 |
| $I_{IO}$ | Input offset current | | vs Temperature | 2 |
| $I_{IB}$ | Input bias current | | vs Temperature | 3 |
| | | | vs Common-mode voltage | 4 |
| $V_{OM+}$ | Maximum positive peak output voltage | | vs Supply voltage | 5 |
| | | | vs Temperature | 6 |
| | | | vs Output current | 7 |
| | | | vs Settling time | 9 |
| $V_{OM-}$ | Maximum negative peak output voltage | | vs Supply voltage | 5 |
| | | | vs Temperature | 6 |
| | | | vs Output current | 8 |
| | | | vs Settling time | 9 |
| $V_{O(PP)}$ | Maximum peak-to-peak output voltage swing | | vs Frequency | 10 |
| $V_{OH}$ | High-level output voltage | | vs Output current | 11 |
| $V_{OL}$ | Low-level output voltage | | vs Output current | 12 |
| $A_{VD}$ | Differential voltage amplification | | vs Temperature | 13 |
| | | | vs Frequency | 14 |
| $z_o$ | Closed loop output impedance | | vs Frequency | 15 |
| $I_{OS}$ | Short-circuit output current | | vs Temperature | 16 |
| CMRR | Common-mode rejection ratio | | vs Frequency | 17 |
| | | | vs Temperature | 18 |
| $k_{SVR}$ | Supply-voltage rejection ratio | | vs Frequency | 19 |
| | | | vs Temperature | 20 |
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| $V_N$ | Noise voltage | | vs Frequency | 23 |
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| SR | Slew rate | | vs Temperature | 27 |
| | | | vs Load capacitance | 28 |
| | Pulse response | Noninverting large-signal | vs Time | 29 |
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| $B_1$ | Unity-gain bandwidth | | vs Load capacitance | 32 |
| | Gain margin | | vs Load capacitance | 33 |
| $\phi_m$ | Phase margin | | vs Load capacitance | 34 |
| | Phase shift | | vs Frequency | 14 |

## TYPICAL CHARACTERISTICS†

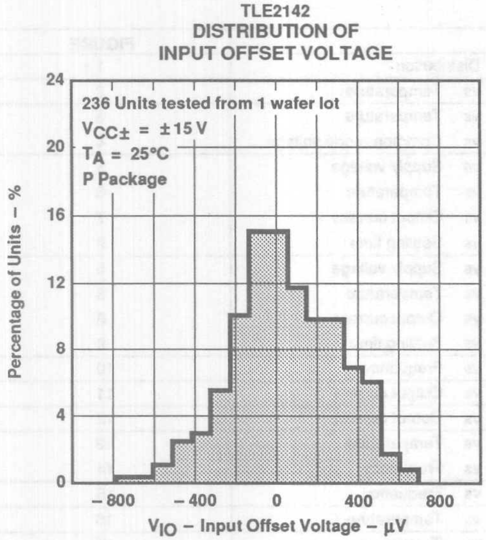
TLE2142
DISTRIBUTION OF
INPUT OFFSET VOLTAGE

Figure 1

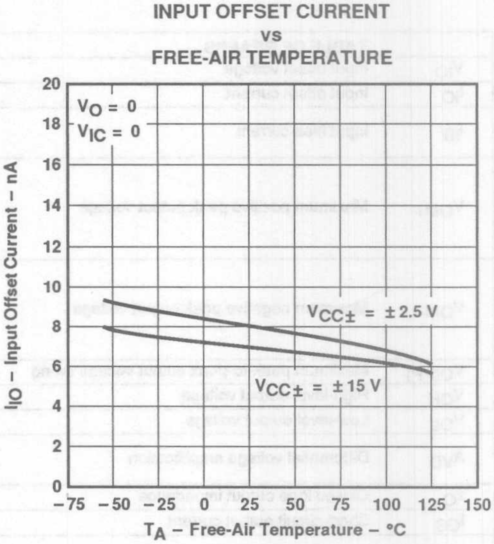
INPUT OFFSET CURRENT
vs
FREE-AIR TEMPERATURE

Figure 2

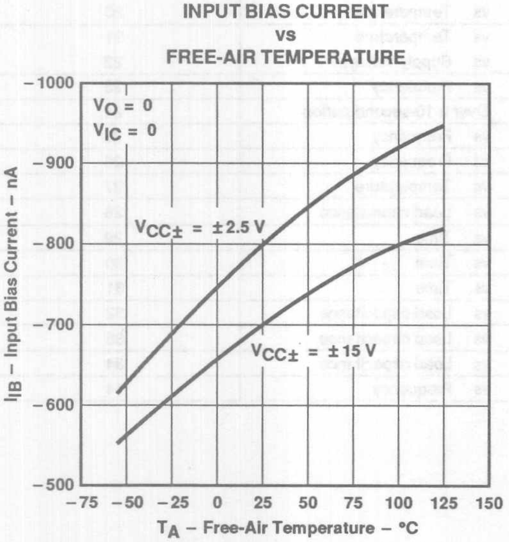
INPUT BIAS CURRENT
vs
FREE-AIR TEMPERATURE

Figure 3

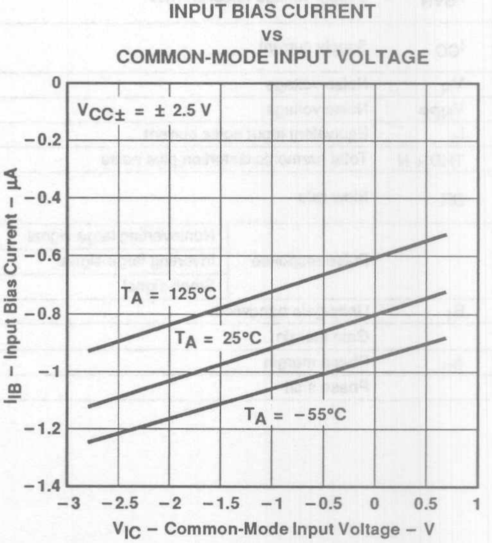
INPUT BIAS CURRENT
vs
COMMON-MODE INPUT VOLTAGE

Figure 4

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†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

**MAXIMUM PEAK OUTPUT VOLTAGE
vs
SUPPLY VOLTAGE**

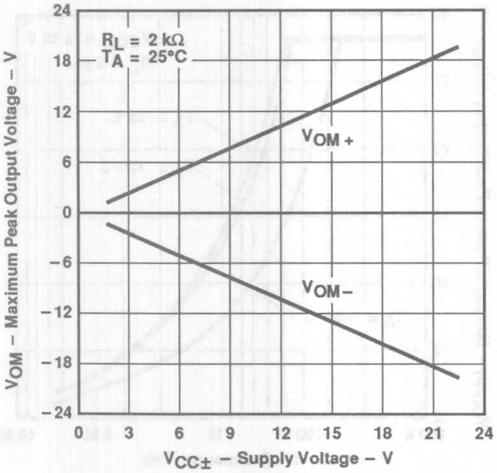

Figure 5

**MAXIMUM PEAK OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE**

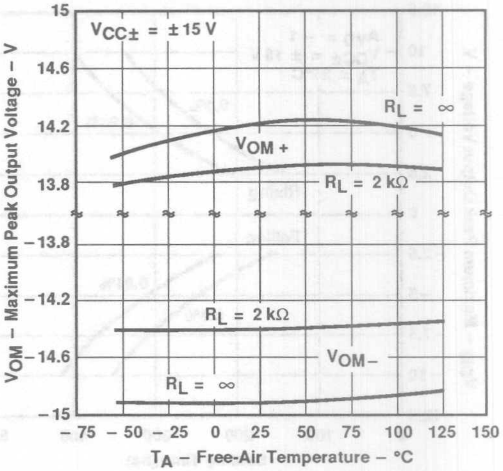

Figure 6

**MAXIMUM POSITIVE PEAK
OUTPUT VOLTAGE
vs
OUTPUT CURRENT**

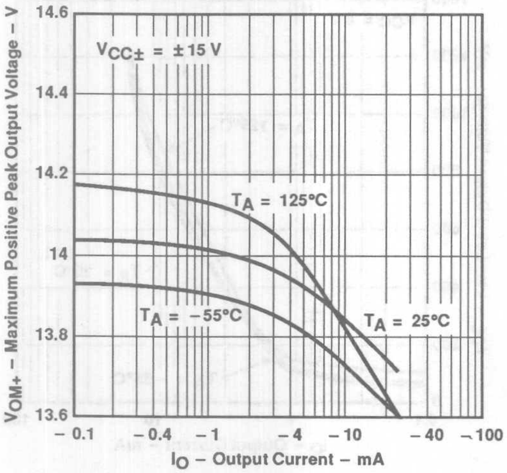

Figure 7

**MAXIMUM NEGATIVE PEAK
OUTPUT VOLTAGE
vs
OUTPUT CURRENT**

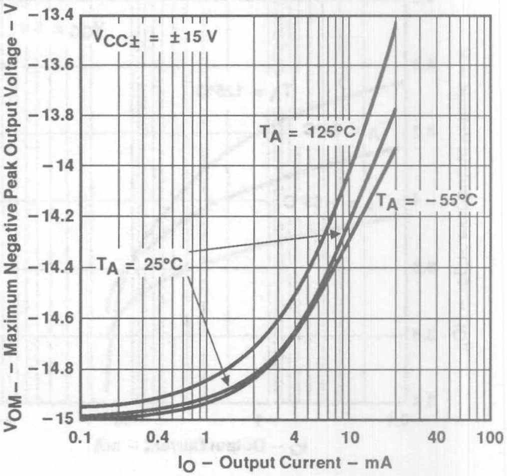

Figure 8

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†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

### MAXIMUM PEAK OUTPUT VOLTAGE vs SETTLING TIME

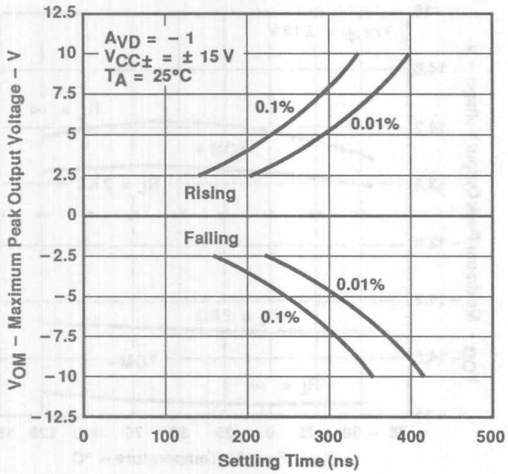

Figure 9

### MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE vs FREQUENCY

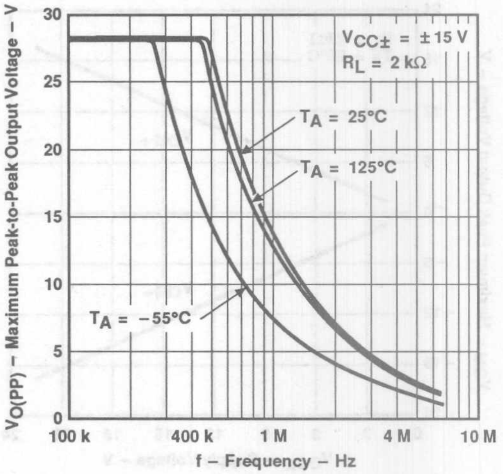

Figure 10

### HIGH-LEVEL OUTPUT VOLTAGE vs OUTPUT CURRENT

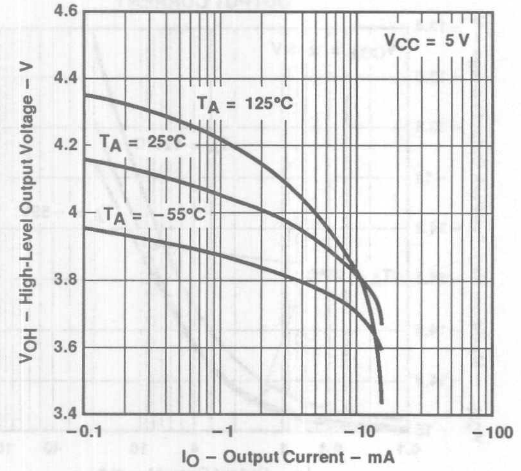

Figure 11

### LOW-LEVEL OUTPUT VOLTAGE vs OUTPUT CURRENT

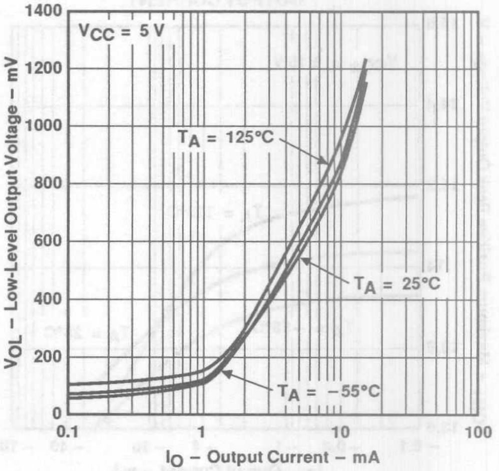

Figure 12

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† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS[†]

### LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION vs FREE-AIR TEMPERATURE

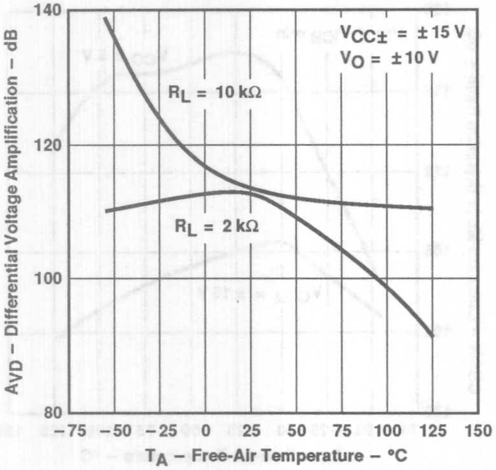

Figure 13

### LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT vs FREQUENCY

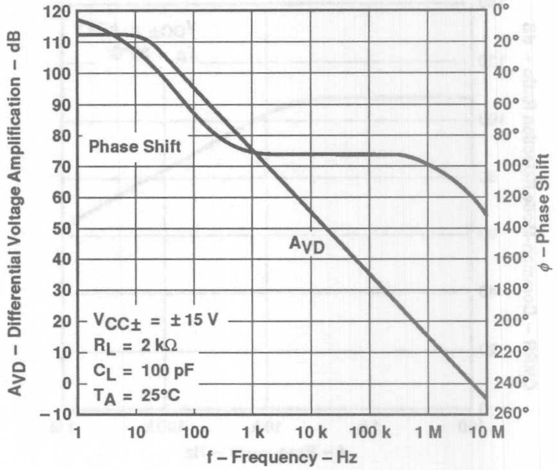

Figure 14

### CLOSED-LOOP OUTPUT IMPEDANCE vs FREQUENCY

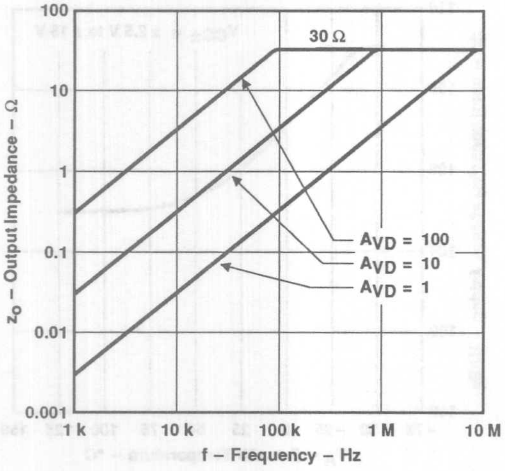

Figure 15

### SHORT-CIRCUIT OUTPUT CURRENT vs FREE-AIR TEMPERATURE

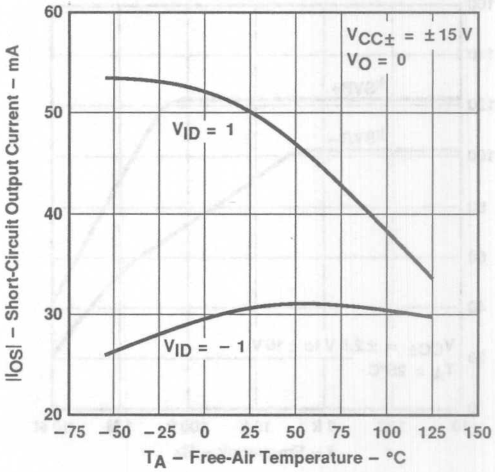

Figure 16

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[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS[†]

COMMON-MODE REJECTION RATIO
vs
FREQUENCY

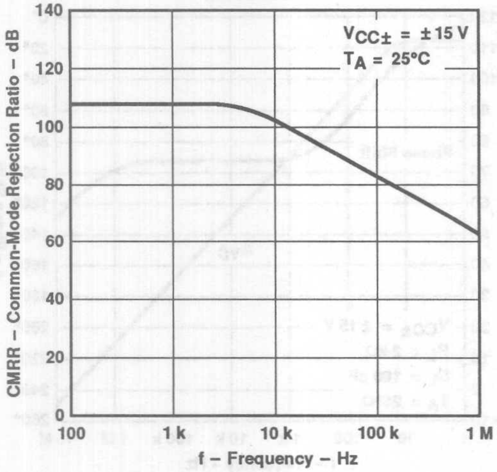

Figure 17

COMMON-MODE REJECTION RATIO
vs
FREE-AIR TEMPERATURE

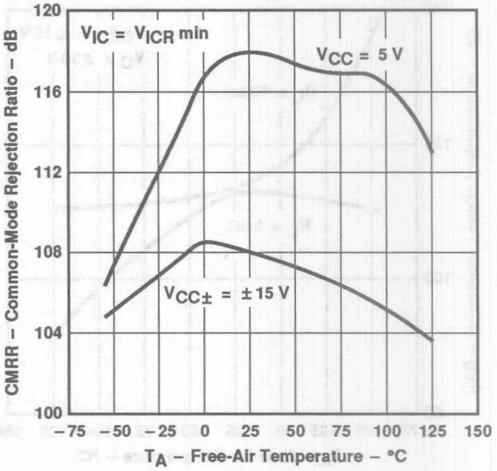

Figure 18

SUPPLY VOLTAGE REJECTION RATIO
vs
FREQUENCY

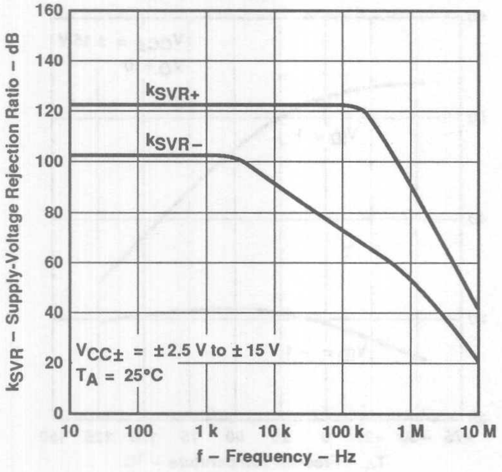

Figure 19

SUPPLY-VOLTAGE REJECTION RATIO
vs
FREE-AIR TEMPERATURE

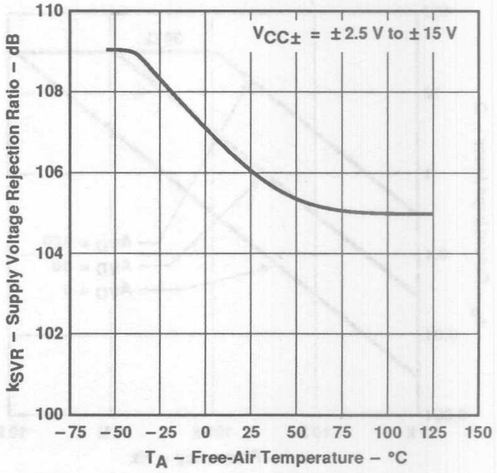

Figure 20

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[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

**SUPPLY CURRENT**
**vs**
**FREE-AIR TEMPERATURE**

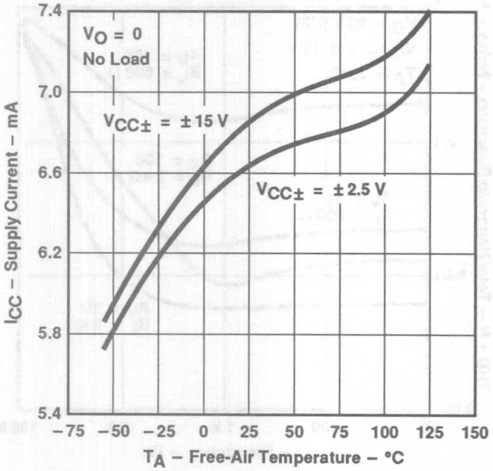

Figure 21

**SUPPLY CURRENT**
**vs**
**SUPPLY VOLTAGE**

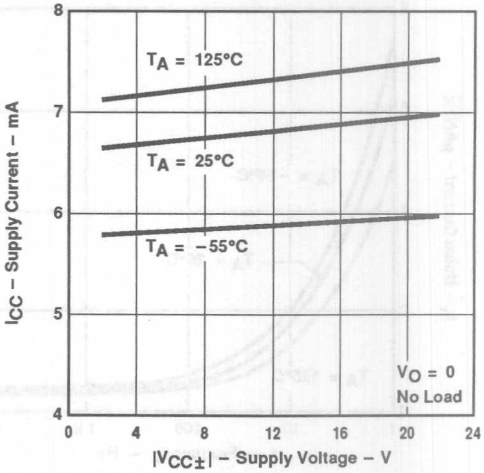

Figure 22

**EQUIVALENT INPUT NOISE VOLTAGE**
**vs**
**FREQUENCY**

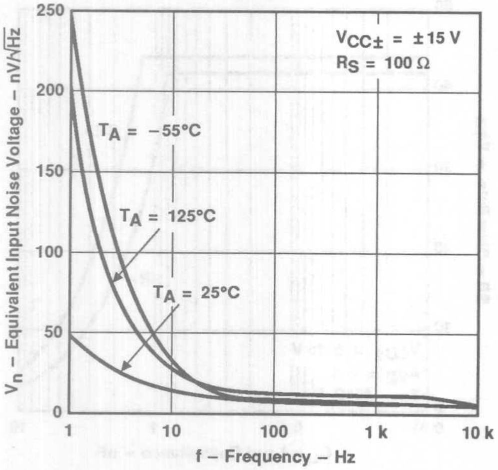

Figure 23

**EQUIVALENT INPUT NOISE VOLTAGE**
**OVER A 10-SECOND PERIOD**

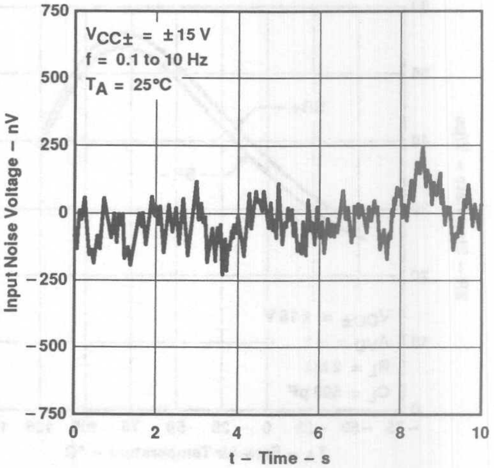

Figure 24

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† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

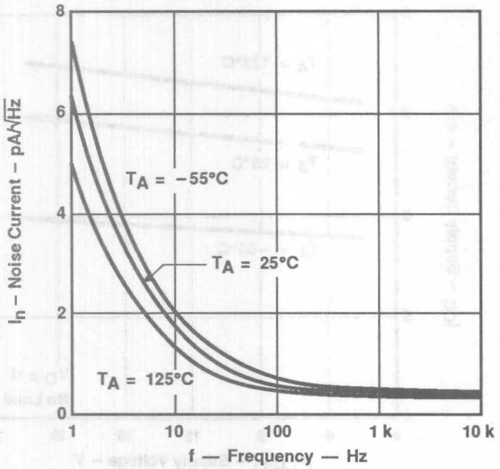
NOISE CURRENT vs FREQUENCY

Figure 25

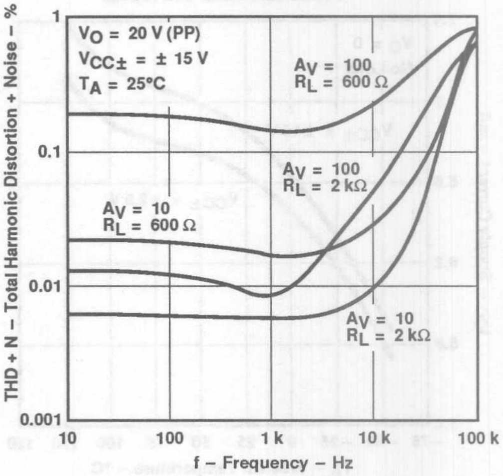
TOTAL HARMONIC DISTORTION PLUS NOISE vs FREQUENCY

Figure 26

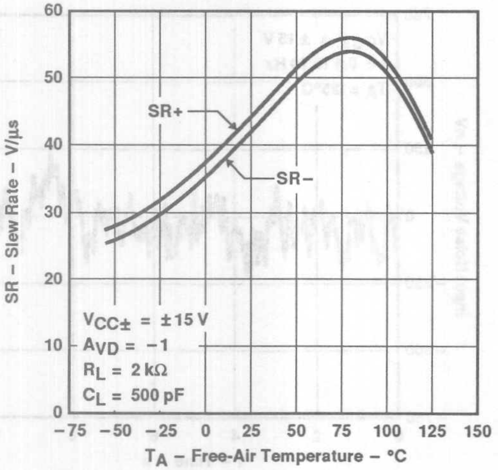
SLEW RATE vs FREE-AIR TEMPERATURE

Figure 27

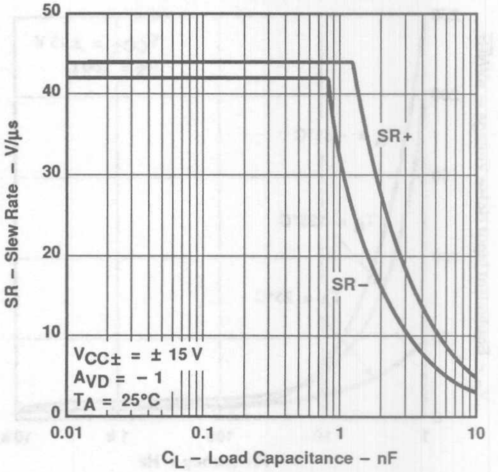
SLEW RATE vs LOAD CAPACITANCE

Figure 28

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†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

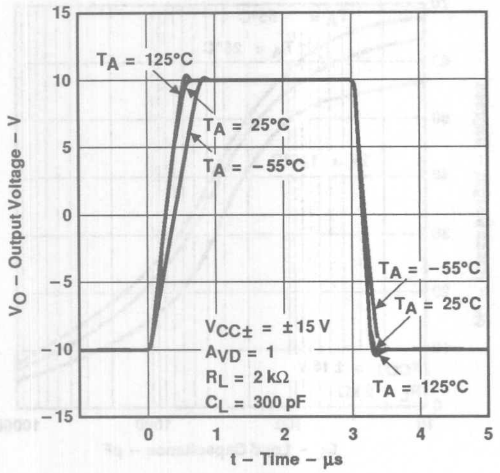
NONINVERTING LARGE-SIGNAL PULSE RESPONSE

Figure 29

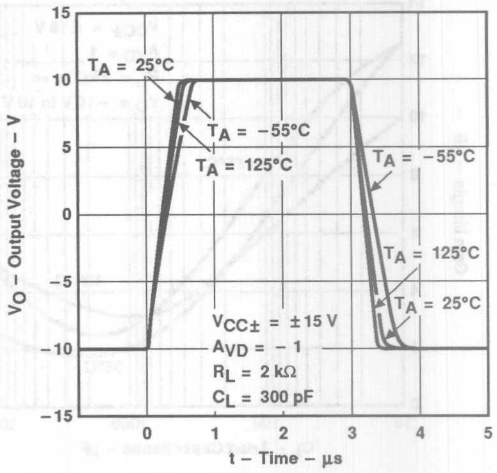
INVERTING LARGE-SIGNAL PULSE RESPONSE

Figure 30

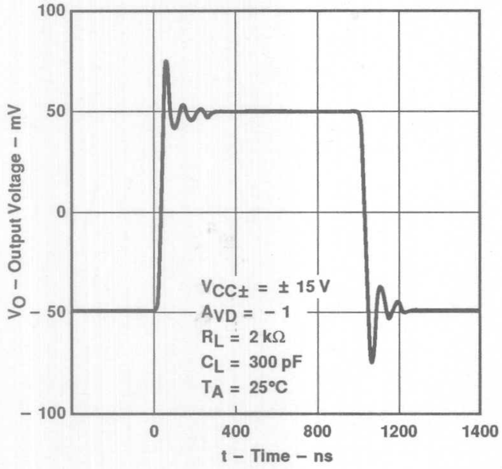
SMALL SIGNAL PULSE RESPONSE

Figure 31

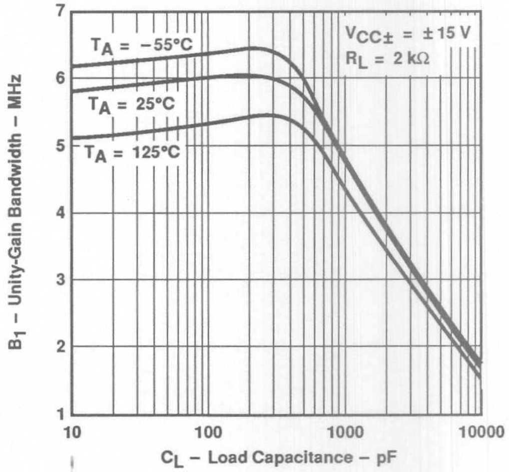
UNITY-GAIN BANDWIDTH vs LOAD CAPACITANCE

Figure 32

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† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS[†]

### GAIN MARGIN vs LOAD CAPACITANCE

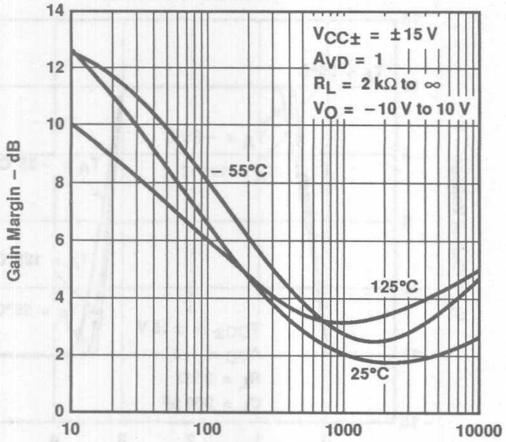

Figure 33

### PHASE MARGIN vs LOAD CAPACITANCE

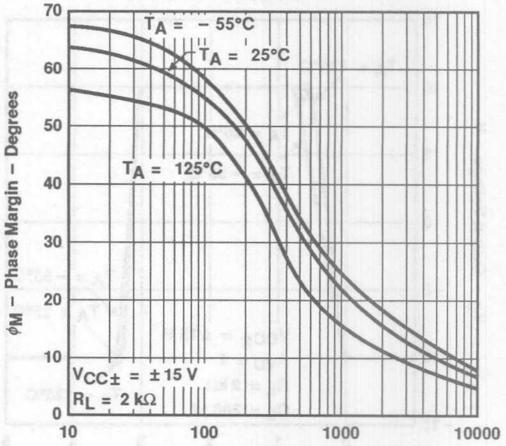

Figure 34

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[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

# TLE2161, TLE2161A, TLE2161B
# EXCALIBUR JFET-INPUT HIGH-OUTPUT-DRIVE µPOWER OPERATIONAL AMPLIFIERS

D3371, NOVEMBER 1989 – REVISED FEBRUARY 1991

## available features

- **Excellent Output Drive Capability**
  **$V_O$ = ± 2.5 V Min at $R_L$ = 100 Ω, $V_{CC\pm}$ = ± 5 V**
  **$V_O$ = ± 12.5 V Min at $R_L$ = 600 Ω, $V_{CC\pm}$ = ± 15 V**
- **Low Supply Current . . . 280 µA Typ**
- **Decompensated for High Slew Rate and Gain-Bandwidth Product**
  **$A_{VD}$ = 5 Min**
  **Slew Rate = 10 V/µs Typ**
  **Gain-Bandwidth Product = 6.5 MHz Typ**
- **Macromodel Included**
- **Wide Operating Supply Voltage Range $V_{CC\pm}$ = ± 3.5 V to ± 20 V**
- **High Open-Loop Gain . . . 280 V/mV Typ**
- **Low Offset Voltage . . . 500 µV Max**
- **Low Offset Voltage Drift With Time 0.04 µV/month Typ**
- **Low Input Bias Current . . . 5 pA Typ**

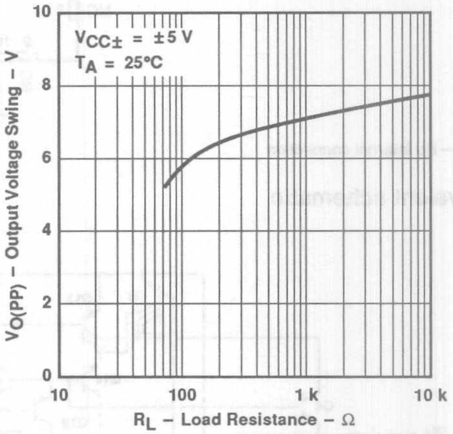
## description

The TLE2161, TLE2161A, and TLE2161B are JFET-input, low-power, precision operational amplifiers manufactured using the Texas Instruments Excalibur process. Decompensated for stability with a minimum closed-loop gain of 5, these devices combine outstanding output drive capability with low power consumption, excellent dc precision, and high gain-bandwidth product.

In addition to maintaining the traditional JFET advantages of fast slew rates and low input bias and offset currents, the Excalibur process offers outstanding parametric stability over time and temperature. This results in a device that remains precise even with changes in temperature and over years of use.

A variety of available options includes small-outline packages and chip-carrier versions for high-density system applications.

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE SWING
vs
LOAD RESISTANCE



AVAILABLE OPTIONS

| $T_A$ | $V_{IO}$ max AT 25°C | PACKAGE | | | | |
|---|---|---|---|---|---|---|
| | | SMALL-OUTLINE (D) | CHIP CARRIER (FK) | CERAMIC DIP (JG) | METAL CAN (L) | PLASTIC DIP (P) |
| 0°C | 500 µV | — | — | — | — | TLE2161BCP |
| to | 1.5 mV | TLE2161ACD | — | — | — | TLE2161ACP |
| 70°C | 3 mV | TLE2161CD | — | — | — | TLE2161CP |
| – 40°C | 500 µV | — | — | — | — | TLE2161BIP |
| to | 1.5 mV | TLE2161AID | — | — | — | TLE2161AIP |
| 85°C | 3 mV | TLE2161ID | — | — | — | TLE2161IP |
| – 55°C | 500 µV | — | — | TLE2161BMJG | TLE2161BML | TLE2161BMP |
| to | 1.5 mV | TLE2161AMD | TLE2161AMFK | TLE2161AMJG | TLE2161AML | TLE2161AMP |
| 125°C | 3 mV | TLE2161MD | TLE2161MFK | TLE2161MJG | TLE2161ML | TLE2161MP |

D packages are available taped and reeled. Add "R" suffix to device type, (e.g., TLE2161ACDR).

PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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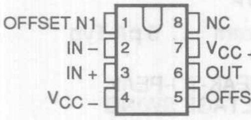
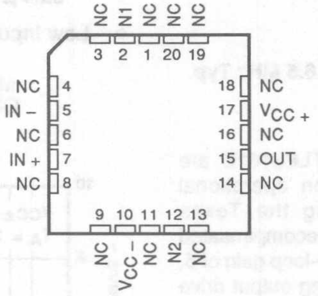
## description (continued)

The C-suffix devices are characterized for operation from 0°C to 70°C . The I-suffix devices are characterized for operation from −40°C to 85°C. The M-suffix devices are characterized for operation over the full military temperature range of −55°C to 125°C.

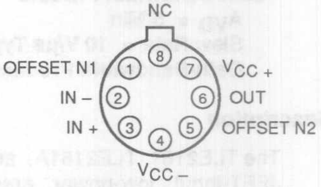
**D, JG, OR P PACKAGE**
**(TOP VIEW)**



**FK PACKAGE**
**(TOP VIEW)**



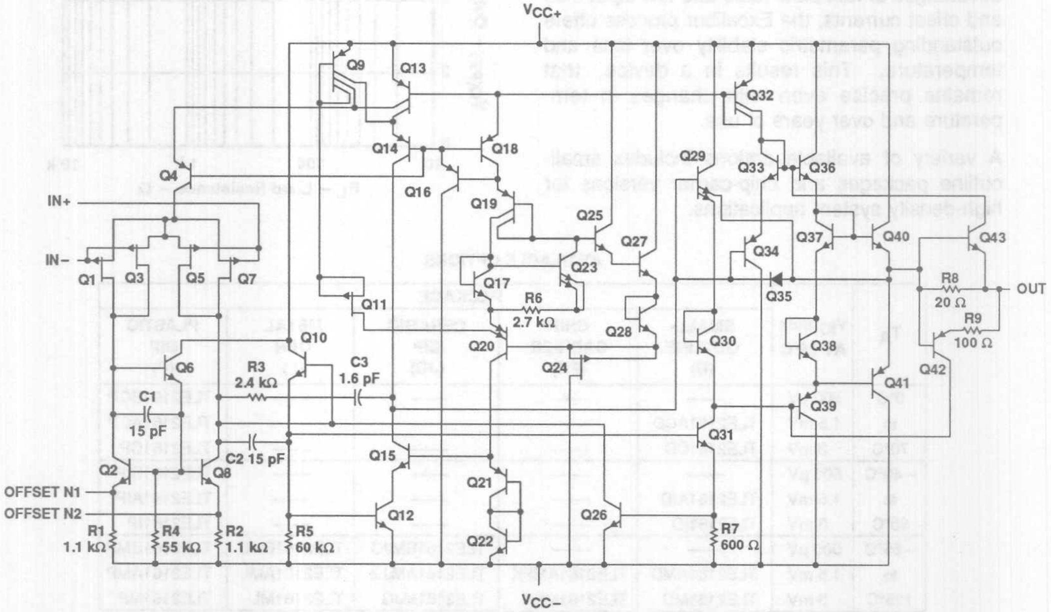
**L PACKAGE**
**(TOP VIEW)**



Pin 4 of the L package is in electrical contact with the case.

NC – No internal connection

## equivalent schematic



All component values are nominal.

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|---|
| Supply voltage, $V_{CC+}$ (see Note 1) | 22 V |
| Supply voltage, $V_{CC-}$ | −22 V |
| Differential input voltage (see Note 2) | ±44 V |
| Input voltage range, $V_I$ (any input) | $V_{CC\pm}$ |
| Input current, $I_I$ (each input) | ±1 mA |
| Output current, $I_O$ | ±80 mA |
| Total current into $V_{CC+}$ terminal | 80 mA |
| Total current out of $V_{CC-}$ terminal | 80 mA |
| Duration of short-circuit current at (or below) 25°C (see Note 3) | unlimited |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range, $T_A$: C-suffix | 0°C to 70°C |
| I-suffix | −40°C to 85°C |
| M-suffix | −55°C to 125°C |
| Storage temperature range | −65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG or L package | 300°C |

NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between $V_{CC+}$ and $V_{CC-}$.
2. Differential voltages are at the noninverting input with respect to the inverting input.
3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \le 25°C$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25°C$ | $T_A = 70°C$ POWER RATING | $T_A = 85°C$ POWER RATING | $T_A = 125°C$ POWER RATING |
|---|---|---|---|---|---|
| D | 725 mW | 5.8 mW/°C | 464 mW | 377 mW | 145 mW |
| FK | 1375 mW | 11.0 mW/°C | 880 mW | 715 mW | 275 mW |
| JG | 1050 mW | 8.4 mW/°C | 672 mW | 546 mW | 210 mW |
| L | 650 mW | 5.2 mW/°C | 416 mW | 338 mW | 130 mW |
| P | 1000 mW | 8.0 mW/°C | 640 mW | 520 mW | 200 mW |

## recommended operating conditions

| | | C-SUFFIX | | I-SUFFIX | | M-SUFFIX | | UNIT |
|---|---|---|---|---|---|---|---|---|
| | | MIN | MAX | MIN | MAX | MIN | MAX | |
| Supply voltage, $V_{CC\pm}$ | | ± 3.5 | ± 20 | ± 3.5 | ± 20 | ± 3.5 | ± 20 | V |
| Common-mode input voltage, $V_{IC}$ | $V_{CC\pm} = \pm 5$ V | − 1.6 | 4 | − 1.6 | 4 | − 1.6 | 4 | V |
| | $V_{CC\pm} = \pm 15$ V | − 11 | 13 | − 11 | 13 | − 11 | 13 | |
| | $V_{CC\pm} = \pm 20$ V | − 15 | 16.5 | − 15 | 16.5 | − 15 | 16.5 | |
| Operating free-air temperature, $T_A$ | | 0 | 70 | − 40 | 85 | − 55 | 125 | °C |

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 5$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2161C | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 0.8 | 3.1 | mV |
| | | | | Full range | | | 4 | |
| | | TLE2161AC | | 25°C | | 0.6 | 2.6 | |
| | | | | Full range | | | 3.5 | |
| | | TLE2161BC | | 25°C | | 0.5 | 1.9 | |
| | | | | Full range | | | 2.4 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | μV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | μV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 1 | | pA |
| | | | | Full range | | | 0.8 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 3 | | pA |
| | | | | Full range | | | 2 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | −1.6 to 4 | −2 to 6 | | V |
| | | | | Full range | −1.6 to 4 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 3.5 | 3.7 | | V |
| | | | | Full range | 3.3 | | | |
| | | | $R_L = 100\ \Omega$ | 25°C | 2.5 | 3.1 | | |
| | | | | Full range | 2 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | −3.7 | −3.9 | | V |
| | | | | Full range | −3.3 | | | |
| | | | $R_L = 100\ \Omega$ | 25°C | −2.5 | −2.7 | | |
| | | | | Full range | −2 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 2.8$ V, $R_L = 10\ k\Omega$ | 25°C | 15 | 80 | | V/mV |
| | | | | Full range | 2 | | | |
| | | | $V_O = 0$ to 2 V, $R_L = 100\ \Omega$ | 25°C | 0.75 | 45 | | |
| | | | | Full range | 0.5 | | | |
| | | | $V_O = 0$ to −2 V, $R_L = 100\ \Omega$ | 25°C | 0.5 | 3 | | |
| | | | | Full range | 0.25 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | 25°C | | 280 | | Ω |
| CMRR | Common-mode rejection ratio | | $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 25°C | 65 | 82 | | dB |
| | | | | Full range | 65 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to $\pm 20$ V, $R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | | | Full range | 75 | | | |
| $I_{CC}$ | Supply current | | $V_O = 0$, No load | 25°C | | 280 | 325 | μA |
| | | | | Full range | | | 350 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | | Full range | | 29 | | μA |

†Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150$°C extrapolated to $T_A = 25$°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| SR | Slew rate (see Figure 1) | $A_{VD} = 5$, $R_L = 10$ kΩ, $C_L = 100$ pF | 25°C | 7 | 10 | | V/μs |
| | | | Full range | 5 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | $R_S = 100$ Ω, f = 10 Hz | 25°C | | 59 | 100 | nV/√Hz |
| | | $R_S = 100$ Ω, f = 1 kHz | | | 43 | 60 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | 25°C | | 1.1 | | μV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | 25°C | | 1 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD} = 5$, $V_{O(PP)} = 2$ V,<br>f = 10 kHz, $R_L = 10$ kΩ | 25°C | | 0.025% | | |
| | Gain-bandwidth product (see Figure 3) | f = 100 kHz, $R_L = 10$ kΩ, $C_L = 100$ pF | 25°C | | 5.8 | | MHz |
| | | f = 100 kHz, $R_L = 100$ Ω, $C_L = 100$ pF | | | 4.3 | | |
| | Settling time | ε = 0.1% | 25°C | | 5 | | μs |
| | | ε = 0.01% | | | 10 | | |
| $B_{OM}$ | Maximum output-swing bandwidth | $A_{VD} = 5$, $R_L = 10$ kΩ | 25°C | | 420 | | kHz |
| $\phi_m$ | Phase margin (see Figure 3) | $A_{VD} = 5$, $R_L = 10$ kΩ, $C_L = 100$ pF | 25°C | | 70° | | |
| | | $A_{VD} = 5$, $R_L = 100$ Ω, $C_L = 100$ pF | | | 84° | | |

†Full range is 0°C to 70°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm}$ = ±15 V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$[†] | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2161C | $V_{IC}$ = 0, $R_S$ = 50 Ω | 25°C | | 0.6 | 3 | mV |
| | | | | Full range | | | 3.9 | |
| | | TLE2161AC | | 25°C | | 0.5 | 1.5 | |
| | | | | Full range | | | 2.5 | |
| | | TLE2161BC | | 25°C | | 0.3 | 0.5 | |
| | | | | Full range | | | 1 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | μV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | μV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 2 | | pA |
| | | | | Full range | | | 1 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 4 | | pA |
| | | | | Full range | | | 3 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | −11<br>to<br>13 | −12<br>to<br>16 | | V |
| | | | | Full range | −11<br>to<br>13 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L$ = 10 kΩ | 25°C | 13.2 | 13.7 | | V |
| | | | | Full range | 13 | | | |
| | | | $R_L$ = 600 Ω | 25°C | 12.5 | 13.2 | | |
| | | | | Full range | 12 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L$ = 10 kΩ | 25°C | −13.2 | −13.7 | | V |
| | | | | Full range | −13 | | | |
| | | | $R_L$ = 600 Ω | 25°C | −12.5 | −13 | | |
| | | | | Full range | −12 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O$ = ±10 V, $R_L$ = 10 kΩ | 25°C | 30 | 230 | | V/mV |
| | | | | Full range | 20 | | | |
| | | | $V_O$ = 0 to 8 V, $R_L$ = 600 Ω | 25°C | 25 | 100 | | |
| | | | | Full range | 10 | | | |
| | | | $V_O$ = 0 to −8 V, $R_L$ = 600 Ω | 25°C | 3 | 25 | | |
| | | | | Full range | 1 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O$ = 0 | 25°C | | 280 | | Ω |
| CMRR | Common-mode rejection ratio | | $V_{IC}$ = $V_{ICR}$ min, $R_S$ = 50 Ω | 25°C | 72 | 90 | | dB |
| | | | | Full range | 70 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$) | | $V_{CC\pm}$ = ±5 V to ±15 V,<br>$R_S$ = 50 Ω | 25°C | 75 | 93 | | dB |
| | | | | Full range | 75 | | | |
| $I_{CC}$ | Supply current | | $V_O$ = 0, No load | 25°C | | 290 | 350 | μA |
| | | | | Full range | | | 375 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | | Full range | | 34 | | μA |

[†] Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A$ = 150°C extrapolated to $T_A$ = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| SR | Slew rate (see Figure 1) | $A_{VD} = 5$, $R_L = 10$ kΩ, $C_L = 100$ pF | 25°C | 7 | 10 | | V/μs |
| | | | Full range | 5 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | $R_S = 100$ Ω, $f = 10$ Hz | 25°C | | 70 | 100 | nV/√Hz |
| | | $R_S = 100$ Ω, $f = 1$ kHz | | | 40 | 60 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | $f = 0.1$ Hz to 10 Hz | 25°C | | 1.1 | | μV |
| $I_n$ | Equivalent input noise current | $f = 1$ kHz | 25°C | | 1.1 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD} = 5$, $V_{O(PP)} = 2$ V, $f = 10$ kHz, $R_L = 10$ kΩ | 25°C | | 0.025% | | |
| | Gain-bandwidth product (see Figure 3) | $f = 100$ kHz, $R_L = 10$ kΩ, $C_L = 100$ pF | 25°C | | 6.4 | | MHz |
| | | $f = 100$ kHz, $R_L = 600$ Ω, $C_L = 100$ pF | | | 5.6 | | |
| | Settling time | $\varepsilon = 0.1\%$ | 25°C | | 5 | | μs |
| | | $\varepsilon = 0.01\%$ | | | 10 | | |
| $B_{OM}$ | Maximum output-swing bandwidth | $A_{VD} = 5$, $R_L = 10$ kΩ | 25°C | | 116 | | kHz |
| $\phi_m$ | Phase margin (see Figure 3) | $A_{VD} = 5$, $R_L = 10$ kΩ, $C_L = 100$ pF | 25°C | | 72° | | |
| | | $A_{VD} = 5$, $R_L = 600$ Ω, $C_L = 100$ pF | | | 78° | | |

† Full range is 0°C to 70°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 20$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2161C | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 0.6 | 3 | mV |
| | | | | Full range | | | 3.9 | |
| | | TLE2161AC | | 25°C | | 0.6 | 1.6 | |
| | | | | Full range | | | 2.5 | |
| | | TLE2161BC | | 25°C | | 0.3 | 0.5 | |
| | | | | Full range | | | 1 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | μV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | μV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 3 | | pA |
| | | | | Full range | | | 1 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 5 | | pA |
| | | | | Full range | | | 3 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | − 15<br>to<br>16.5 | − 17<br>to<br>21 | | V |
| | | | | Full range | − 15<br>to<br>16.5 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 18.2 | 18.7 | | V |
| | | | | Full range | 18 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | 15 | 18.1 | | |
| | | | | Full range | 12 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | − 18.2 | − 18.7 | | V |
| | | | | Full range | − 18 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | − 15 | − 18 | | |
| | | | | Full range | − 12 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 15$ V, $R_L = 10\ k\Omega$ | 25°C | 30 | 280 | | V/mV |
| | | | | Full range | 20 | | | |
| | | | $V_O = 0$ to 10 V, $R_L = 600\ \Omega$ | 25°C | 25 | 80 | | |
| | | | | Full range | 10 | | | |
| | | | $V_O = 0$ to − 10 V, $R_L = 600\ \Omega$ | 25°C | 3 | 20 | | |
| | | | | Full range | 1 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | 25°C | | 280 | | Ω |
| CMRR | Common-mode rejection ratio | | $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 25°C | 75 | 91 | | dB |
| | | | | Full range | 70 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to $\pm 20$ V, $R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | | | Full range | 70 | | | |
| $I_{CC}$ | Supply current | | $V_O = 0$, No load | 25°C | | 300 | 375 | μA |
| | | | | Full range | | | 400 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | | Full range | | 18 | | μA |

†Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm}$ = ± 20 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| SR | Slew rate (see Figure 1) | $A_{VD}$ = 5, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | 7 | 10 | | V/μs |
| | | | Full range | 5 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | $R_S$ = 100 Ω, f = 10 Hz | 25°C | | 75 | 100 | nV/√Hz |
| | | $R_S$ = 100 Ω, f = 1 kHz | | | 40 | 60 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | 25°C | | 1.1 | | μV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | 25°C | | 1.3 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD}$ = 5, $V_{O(PP)}$ = 2 V,<br>f = 10 kHz, $R_L$ = 10 kΩ | 25°C | | 0.025% | | |
| | Gain-bandwidth product (see Figure 3) | f = 100 kHz, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 6.5 | | MHz |
| | | f = 100 kHz, $R_L$ = 600 Ω, $C_L$ = 100 pF | | | 5.7 | | |
| | Settling time | ε = 0.1% | 25°C | | 5 | | μs |
| | | ε = 0.01% | | | 10 | | |
| $B_{OM}$ | Maximum output-swing bandwidth | $A_{VD}$ = 5, $R_L$ = 10 kΩ | 25°C | | 85 | | kHz |
| $\phi_m$ | Phase margin (see Figure 3) | $A_{VD}$ = 5, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 72° | | |
| | | $A_{VD}$ = 5, $R_L$ = 600 Ω, $C_L$ = 100 pF | | | 78° | | |

†Full range is 0°C to 70°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm5$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2161I | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 0.8 | 3.1 | mV |
| | | | | Full range | | | 4.4 | |
| | | TLE2161AI | | 25°C | | 0.6 | 2.6 | |
| | | | | Full range | | | 3.9 | |
| | | TLE2161BI | | 25°C | | 0.5 | 1.9 | |
| | | | | Full range | | | 2.7 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | μV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | μV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 1 | | pA |
| | | | | Full range | | | 2 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 3 | | pA |
| | | | | Full range | | | 4 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | − 1.6 to 4 | − 2 to 6 | | V |
| | | | | Full range | − 1.6 to 4 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 3.5 | 3.7 | | V |
| | | | | Full range | 3.1 | | | |
| | | | $R_L = 100\ \Omega$ | 25°C | 2.5 | 3.1 | | |
| | | | | Full range | 2 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | − 3.7 | − 3.9 | | V |
| | | | | Full range | − 3.1 | | | |
| | | | $R_L = 100\ \Omega$ | 25°C | − 2.5 | − 2.7 | | |
| | | | | Full range | − 2 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm2.8$ V, $R_L = 10\ k\Omega$ | 25°C | 15 | 80 | | V/mV |
| | | | | Full range | 2 | | | |
| | | | $V_O = 0$ to 2 V, $R_L = 100\ \Omega$ | 25°C | 0.75 | 45 | | |
| | | | | Full range | 0.5 | | | |
| | | | $V_O = 0$ to − 2 V, $R_L = 100\ \Omega$ | 25°C | 0.5 | 3 | | |
| | | | | Full range | 0.25 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | 25°C | | 280 | | Ω |
| CMRR | Common-mode rejection ratio | | $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 25°C | 65 | 82 | | dB |
| | | | | Full range | 65 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$) | | $V_{CC\pm} = \pm5$ V to ± 20 V, $R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | | | Full range | 65 | | | |
| $I_{CC}$ | Supply current | | $V_O = 0$, No load | 25°C | | 280 | 325 | μA |
| | | | | Full range | | | 350 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | | Full range | | 29 | | μA |

†Full range is – 40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm}$ = ± 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$[†] | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| SR | Slew rate (see Figure 1) | $A_{VD}$ = 5, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | 7 | 10 | | V/μs |
| | | | Full range | 5 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | $R_S$ = 100 Ω, f = 10 Hz | 25°C | | 59 | 100 | nV/√Hz |
| | | $R_S$ = 100 Ω, f = 1 kHz | | | 43 | 60 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | 25°C | | 1.1 | | μV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | 25°C | | 1 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD}$ = 5, $V_{O(PP)}$ = 2 V, f = 10 kHz, $R_L$ = 10 kΩ | 25°C | | 0.025% | | |
| | Gain-bandwidth product (see Figure 3) | f = 100 kHz, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 5.8 | | MHz |
| | | f = 100 kHz, $R_L$ = 100 Ω, $C_L$ = 100 pF | | | 4.3 | | |
| | Settling time | ε = 0.1% | 25°C | | 5 | | μs |
| | | ε = 0.01% | | | 10 | | |
| $B_{OM}$ | Maximum output-swing bandwidth | $A_{VD}$ = 5, $R_L$ = 10 kΩ | 25°C | | 420 | | kHz |
| $\phi_m$ | Phase margin (see Figure 3) | $A_{VD}$ = 5, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 70° | | |
| | | $A_{VD}$ = 5, $R_L$ = 100 Ω, $C_L$ = 100 pF | | | 84° | | |

[†] Full range is – 40°C to 85°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2161I | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 0.6 | 3 | mV |
| | | | | Full range | | | 4.3 | |
| | | TLE2161AI | | 25°C | | 0.5 | 1.5 | |
| | | | | Full range | | | 2.9 | |
| | | TLE2161BI | | 25°C | | 0.3 | 0.5 | |
| | | | | Full range | | | 1.3 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | µV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 2 | | pA |
| | | | | Full range | | | 3 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 4 | | pA |
| | | | | Full range | | | 5 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | − 11<br>to<br>13 | − 12<br>to<br>16 | | V |
| | | | | Full range | − 11<br>to<br>13 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 13.2 | 13.7 | | V |
| | | | | Full range | 13 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | 12.5 | 13.2 | | |
| | | | | Full range | 12 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | − 13.2 | − 13.7 | | V |
| | | | | Full range | − 13 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | − 12.5 | − 13 | | |
| | | | | Full range | − 12 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 10$ V, $R_L = 10\ k\Omega$ | 25°C | 30 | 230 | | V/mV |
| | | | | Full range | 20 | | | |
| | | | $V_O = 0$ to 8 V, $R_L = 600\ \Omega$ | 25°C | 25 | 100 | | |
| | | | | Full range | 10 | | | |
| | | | $V_O = 0$ to − 8 V, $R_L = 600\ \Omega$ | 25°C | 3 | 25 | | |
| | | | | Full range | 1 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | 25°C | | 280 | | Ω |
| CMRR | Common-mode rejection ratio | | $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 25°C | 72 | 90 | | dB |
| | | | | Full range | 65 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to ± 15 V,<br>$R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | | | Full range | 65 | | | |
| $I_{CC}$ | Supply current | | $V_O = 0$, No load | 25°C | | 290 | 350 | µA |
| | | | | Full range | | | 375 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | | Full range | | 34 | | µA |

†Full range is − 40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm}$ = ±15 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| SR | Slew rate (see Figure 1) | $A_{VD}$ = 5, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | 7 | 10 | | V/μs |
| | | | Full range | 5 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | $R_S$ = 100 Ω, f = 10 Hz | 25°C | | 70 | 100 | nV/√Hz |
| | | $R_S$ = 100 Ω, f = 1 kHz | | | 40 | 60 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | 25°C | | 1.1 | | μV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | 25°C | | 1.1 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD}$ = 5, $V_{O(PP)}$ = 2 V,<br>f = 10 kHz, $R_L$ = 10 kΩ | 25°C | | 0.025% | | |
| | Gain-bandwidth product (see Figure 3) | f = 100 kHz, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 6.4 | | MHz |
| | | f = 100 kHz, $R_L$ = 600 Ω, $C_L$ = 100 pF | | | 5.6 | | |
| | Settling time | ε = 0.1% | 25°C | | 5 | | μs |
| | | ε = 0.01% | | | 10 | | |
| $B_{OM}$ | Maximum output-swing bandwidth | $A_{VD}$ = 5, $R_L$ = 10 kΩ | 25°C | | 116 | | kHz |
| $\phi_m$ | Phase margin (see Figure 3) | $A_{VD}$ = 5, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 72° | | |
| | | $A_{VD}$ = 5, $R_L$ = 600 Ω, $C_L$ = 100 pF | | | 78° | | |

† Full range is – 40°C to 85°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 20$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2161I | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 0.6 | 3 | mV |
| | | | | Full range | | | 4.3 | |
| | | TLE2161AI | | 25°C | | 0.6 | 1.6 | |
| | | | | Full range | | | 2.9 | |
| | | TLE2161BI | | 25°C | | 0.3 | 0.5 | |
| | | | | Full range | | | 1.3 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | μV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | μV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 3 | | pA |
| | | | | Full range | | | 3 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 5 | | pA |
| | | | | Full range | | | 5 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | − 15 to 16.5 | − 17 to 21 | | V |
| | | | | Full range | − 15 to 16.5 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 18.2 | 18.7 | | V |
| | | | | Full range | 18 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | 15 | 18.1 | | |
| | | | | Full range | 12 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | − 18.2 | − 18.7 | | V |
| | | | | Full range | − 18 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | − 15 | − 18 | | |
| | | | | Full range | − 12 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 15$ V, $R_L = 10\ k\Omega$ | 25°C | 30 | 280 | | V/mV |
| | | | | Full range | 20 | | | |
| | | | $V_O = 0$ to 10 V, $R_L = 600\ \Omega$ | 25°C | 25 | 80 | | |
| | | | | Full range | 10 | | | |
| | | | $V_O = 0$ to − 10 V, $R_L = 600\ \Omega$ | 25°C | 3 | 20 | | |
| | | | | Full range | 1 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | 25°C | | 280 | | Ω |
| CMRR | Common-mode rejection ratio | | $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 25°C | 75 | 91 | | dB |
| | | | | Full range | 65 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to $\pm 20$ V, $R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | | | Full range | 65 | | | |
| $I_{CC}$ | Supply current | | $V_O = 0$, No load | 25°C | | 300 | 375 | μA |
| | | | | Full range | | | 400 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | | Full range | | 36 | | μA |

†Full range is − 40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm}$ = ±20 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| SR | Slew rate (see Figure 1) | $A_{VD}$ = 5, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | 7 | 10 | | V/µs |
| | | | Full range | 5 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | $R_S$ = 100 Ω, f = 10 Hz | 25°C | | 75 | 100 | nV/√Hz |
| | | $R_S$ = 100 Ω, f = 1 kHz | | | 40 | 60 | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | 25°C | | 1.1 | | µV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | 25°C | | 1.3 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD}$ = 5, $V_{O(PP)}$ = 2 V,<br>f = 10 kHz, $R_L$ = 10 kΩ | 25°C | | 0.025% | | |
| | Gain-bandwidth product (see Figure 3) | f = 100 kHz, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 6.5 | | MHz |
| | | f = 100 kHz, $R_L$ = 600 Ω, $C_L$ = 100 pF | | | 5.7 | | |
| | Settling time | ε = 0.1% | 25°C | | 5 | | µs |
| | | ε = 0.01% | | | 10 | | |
| $B_{OM}$ | Maximum output-swing bandwidth | $A_{VD}$ = 5, $R_L$ = 10 kΩ | 25°C | | 85 | | kHz |
| $\phi_m$ | Phase margin (see Figure 3) | $A_{VD}$ = 5, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 72° | | |
| | | $A_{VD}$ = 5, $R_L$ = 600 Ω, $C_L$ = 100 pF | | | 78° | | |

†Full range is – 40°C to 85°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 5$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2161M | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 0.8 | 3.1 | mV |
| | | | | Full range | | | 6 | |
| | | TLE2161AM | | 25°C | | 0.6 | 2.6 | |
| | | | | Full range | | | 4.6 | |
| | | TLE2161BM | | 25°C | | 0.5 | 1.9 | |
| | | | | Full range | | | 3.1 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | μV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | μV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 1 | | pA |
| | | | | Full range | | | 15 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 3 | | pA |
| | | | | Full range | | | 30 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | − 1.6 to 4 | − 2 to 6 | | V |
| | | | | Full range | − 1.6 to 4 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 3.5 | 3.7 | | V |
| | | | | Full range | 3 | | | |
| | | FK, JG, and L packages | $R_L = 600\ \Omega$ | 25°C | 2.5 | 3.6 | | |
| | | | | Full range | 2 | | | |
| | | D and P packages | $R_L = 100\ \Omega$ | 25°C | 2.5 | 3.1 | | |
| | | | | Full range | 2 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | − 3.7 | − 3.9 | | V |
| | | | | Full range | − 3 | | | |
| | | FK, JG, and L packages | $R_L = 600\ \Omega$ | 25°C | − 2.5 | − 3.5 | | |
| | | | | Full range | − 2 | | | |
| | | D and P packages | $R_L = 100\ \Omega$ | 25°C | − 2.5 | − 2.7 | | |
| | | | | Full range | − 2 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 2.8$ V, $R_L = 10\ k\Omega$ | 25°C | 15 | 80 | | V/mV |
| | | | | Full range | 2 | | | |
| | | FK, JG, and L packages | $V_O = 0$ to 2.5 V, $R_L = 600\ \Omega$ | 25°C | 1 | 65 | | |
| | | | | Full range | 0.5 | | | |
| | | | $V_O = 0$ to − 2.5 V, $R_L = 600\ \Omega$ | 25°C | 1 | 16 | | |
| | | | | Full range | 0.5 | | | |
| | | D and P packages | $V_O = 0$ to 2 V, $R_L = 100\ \Omega$ | 25°C | 0.75 | 45 | | |
| | | | | Full range | 0.5 | | | |
| | | | $V_O = 0$ to − 2 V, $R_L = 100\ \Omega$ | 25°C | 0.5 | 3 | | |
| | | | | Full range | 0.25 | | | |

† Full range is − 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150$°C extrapolated to $T_A = 25$°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 5$ V (unless otherwise noted) (continued)

| PARAMETER | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $r_i$ | Input resistance | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | $I_O = 0$ | 25°C | | 280 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 25°C | 65 | 82 | | dB |
| | | | Full range | 60 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 5$ V to ±20 V,<br>$R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | | Full range | 65 | | | |
| $I_{CC}$ | Supply current | $V_O = 0$, No load | 25°C | | 280 | 325 | μA |
| | | | Full range | | | 350 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | Full range | | 39 | | μA |

†Full range is – 55°C to 125°C.

## operating characteristics, $V_{CC\pm} = \pm 5$ V, $T_A = 25°C$

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| SR | Slew rate (see Figure 1) | $A_{VD} = 5$, $R_L = 10\ k\Omega$, $C_L = 100$ pF | | 10 | | V/μs |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | $R_S = 100\ \Omega$, f = 10 Hz | | 59 | | nV/√Hz |
| | | $R_S = 100\ \Omega$, f = 1 kHz | | 43 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | | 1.1 | | μV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | 1 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD} = 5$, $V_{O(PP)} = 2$ V,<br>f = 10 kHz, $R_L = 10\ k\Omega$ | | 0.025% | | |
| | Gain-bandwidth product (see Figure 3) | f = 100 kHz, $R_L = 10\ k\Omega$, $C_L = 100$ pF | | 5.8 | | MHz |
| | | f = 100 kHz, $R_L = 600\ \Omega$, $C_L = 100$ pF | | 4.3 | | |
| | Settling time | ε = 0.1% | | 5 | | μs |
| | | ε = 0.01% | | 10 | | |
| $B_{OM}$ | Maximum output-swing bandwidth | $A_{VD} = 5$, $R_L = 10\ k\Omega$ | | 420 | | kHz |
| $\phi_m$ | Phase margin (see Figure 3) | $A_{VD} = 5$, $R_L = 10\ k\Omega$, $C_L = 100$ pF | | 70° | | |
| | | $A_{VD} = 5$, $R_L = 600\ \Omega$, $C_L = 100$ pF | | 84° | | |

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2161M | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 0.6 | 3 | mV |
| | | | | Full range | | | 6 | |
| | | TLE2161AM | | 25°C | | 0.5 | 1.5 | |
| | | | | Full range | | | 3.6 | |
| | | TLE2161BM | | 25°C | | 0.3 | 0.5 | |
| | | | | Full range | | | 1.7 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | µV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | µV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 2 | | pA |
| | | | | Full range | | | 20 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 4 | | pA |
| | | | | Full range | | | 40 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | − 11<br>to<br>13 | −12<br>to<br>16 | | V |
| | | | | Full range | − 11<br>to<br>13 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 13.2 | 13.7 | | V |
| | | | | Full range | 12.5 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | 12.5 | 13.2 | | |
| | | | | Full range | 12 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | − 13.2 | − 13.7 | | V |
| | | | | Full range | − 12.5 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | − 12.5 | − 13 | | |
| | | | | Full range | − 12 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 10$ V, $R_L = 10\ k\Omega$ | 25°C | 30 | 230 | | V/mV |
| | | | | Full range | 20 | | | |
| | | | $V_O = 0$ to 8 V, $R_L = 600\ \Omega$ | 25°C | 25 | 100 | | |
| | | | | Full range | 7 | | | |
| | | | $V_O = 0$ to − 8 V, $R_L = 600\ \Omega$ | 25°C | 3 | 25 | | |
| | | | | Full range | 1 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | 25°C | | 280 | | Ω |
| CMRR | Common-mode rejection ratio | | $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 25°C | 72 | 90 | | dB |
| | | | | Full range | 65 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to ± 15 V,<br>$R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | | | Full range | 65 | | | |
| $I_{CC}$ | Supply current | | $V_O = 0$, No load | 25°C | | 290 | 350 | µA |
| | | | | Full range | | | 375 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | | Full range | | 46 | | µA |

†Full range is − 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

## operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| SR | Slew rate (see Figure 1) | $A_{VD}$ = 5, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | 7 | 10 | | V/μs |
| | | | Full range | 5 | | | |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | $R_S$ = 100 Ω, f = 10 Hz | 25°C | | 70 | | nV/√Hz |
| | | $R_S$ = 100 Ω, f = 1 kHz | | | 40 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 10 Hz | 25°C | | 1.1 | | μV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | 25°C | | 1.1 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD}$ = 5, $V_{O(PP)}$ = 2 V, f = 10 kHz, $R_L$ = 10 kΩ | 25°C | | 0.025% | | |
| | Gain-bandwidth product (see Figure 3) | f = 100 kHz, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 6.4 | | MHz |
| | | f = 100 kHz, $R_L$ = 600 Ω, $C_L$ = 100 pF | | | 5.6 | | |
| | Settling time | ε = 0.1% | 25°C | | 5 | | μs |
| | | ε = 0.01% | | | 10 | | |
| $B_{OM}$ | Maximum output-swing bandwidth | $A_{VD}$ = 5, $R_L$ = 10 kΩ | 25°C | | 116 | | kHz |
| $\phi_m$ | Phase margin (see Figure 3) | $A_{VD}$ = 5, $R_L$ = 10 kΩ, $C_L$ = 100 pF | 25°C | | 72° | | |
| | | $A_{VD}$ = 5, $R_L$ = 600 Ω, $C_L$ = 100 pF | | | 78° | | |

† Full range is – 55°C to 125°C.

## electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 20$ V (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | $T_A$† | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{IO}$ | Input offset voltage | TLE2161M | $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 0.6 | 3 | mV |
| | | | | Full range | | | 6 | |
| | | TLE2161AM | | 25°C | | 0.6 | 1.6 | |
| | | | | Full range | | | 3.6 | |
| | | TLE2161BM | | 25°C | | 0.3 | 0.5 | |
| | | | | Full range | | | 1.7 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | Full range | | 6 | | μV/°C |
| | Input offset voltage long-term drift (see Note 4) | | | 25°C | | 0.04 | | μV/mo |
| $I_{IO}$ | Input offset current | | | 25°C | | 3 | | pA |
| | | | | Full range | | | 20 | nA |
| $I_{IB}$ | Input bias current | | | 25°C | | 5 | | pA |
| | | | | Full range | | | 40 | nA |
| $V_{ICR}$ | Common-mode input voltage range | | | 25°C | −15 to 16.5 | −17 to 21 | | V |
| | | | | Full range | −15 to 16.5 | | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | 18.2 | 18.7 | | V |
| | | | | Full range | 17.5 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | 15 | 18.1 | | |
| | | | | Full range | 12 | | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | | $R_L = 10\ k\Omega$ | 25°C | −18.2 | −18.7 | | V |
| | | | | Full range | −17.5 | | | |
| | | | $R_L = 600\ \Omega$ | 25°C | −15 | −18 | | |
| | | | | Full range | −12 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | | $V_O = \pm 15$ V, $R_L = 10\ k\Omega$ | 25°C | 30 | 280 | | V/mV |
| | | | | Full range | 20 | | | |
| | | | $V_O = 0$ to 10 V, $R_L = 600\ \Omega$ | 25°C | 25 | 80 | | |
| | | | | Full range | 10 | | | |
| | | | $V_O = 0$ to −10 V, $R_L = 600\ \Omega$ | 25°C | 3 | 20 | | |
| | | | | Full range | 1 | | | |
| $r_i$ | Input resistance | | | 25°C | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 25°C | | 4 | | pF |
| $z_o$ | Open-loop output impedance | | $I_O = 0$ | 25°C | | 280 | | Ω |
| CMRR | Common-mode rejection ratio | | $V_{IC} = V_{ICR}$ min, $R_S = 50\ \Omega$ | 25°C | 75 | 91 | | dB |
| | | | | Full range | 65 | | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | | $V_{CC\pm} = \pm 5$ V to ± 20 V, $R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | | | Full range | 65 | | | |
| $I_{CC}$ | Supply current | | $V_O = 0$, No load | 25°C | | 300 | 375 | μA |
| | | | | Full range | | | 400 | |
| $\Delta I_{CC}$ | Supply current change over operating temperature range | | | Full range | | 50 | | μA |

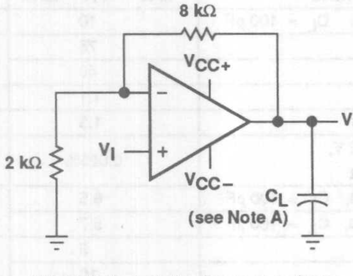
†Full range is − 55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150°C$ extrapolated to $T_A = 25°C$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

### operating characteristics, $V_{CC\pm} = \pm 20$ V, $T_A = 25°C$

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| SR | Slew rate (see Figure 1) | $A_{VD} = 5$, $R_L = 10\ k\Omega$, $C_L = 100$ pF | | 10 | | V/μs |
| $V_n$ | Equivalent input noise voltage (see Figure 2) | $R_S = 100\ \Omega$, $f = 10$ Hz | | 75 | | nV/√Hz |
| | | $R_S = 100\ \Omega$, $f = 1$ kHz | | 40 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | $f = 0.1$ Hz to 10 Hz | | 1.1 | | μV |
| $I_n$ | Equivalent input noise current | $f = 1$ kHz | | 1.3 | | fA/√Hz |
| THD | Total harmonic distortion | $A_{VD} = 5$, $V_{O(PP)} = 2$ V,<br>$f = 10$ kHz, $R_L = 10\ k\Omega$ | | 0.025% | | |
| | Gain-bandwidth product (see Figure 3) | $f = 100$ kHz, $R_L = 10\ k\Omega$, $C_L = 100$ pF | | 6.5 | | MHz |
| | | $f = 100$ kHz, $R_L = 600\ \Omega$, $C_L = 100$ pF | | 5.7 | | |
| | Settling time | $\varepsilon = 0.1\%$ | | 5 | | μs |
| | | $\varepsilon = 0.01\%$ | | 10 | | |
| $B_{OM}$ | Maximum output-swing bandwidth | $A_{VD} = 5$, $R_L = 10\ k\Omega$ | | 85 | | kHz |
| $\phi_m$ | Phase margin (see Figure 3) | $A_{VD} = 5$, $R_L = 10\ k\Omega$, $C_L = 100$ pF | | 72° | | |
| | | $A_{VD} = 5$, $R_L = 600\ \Omega$, $C_L = 100$ pF | | 78° | | |

## PARAMETER MEASUREMENT INFORMATION



NOTE A: $C_L$ includes fixture capacitance.

**Figure 1. Slew Rate Test Circuit**

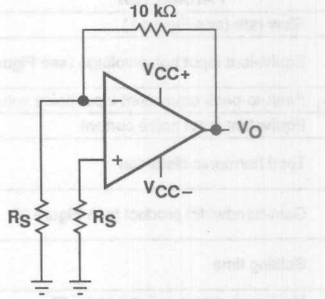
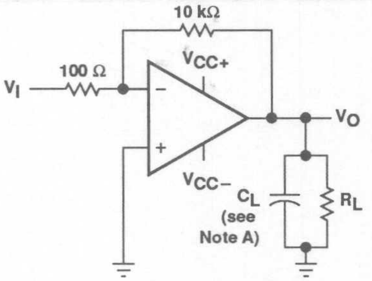


**Figure 2. Noise Voltage Test Circuit**



NOTE A: $C_L$ includes fixture capacitance.

**Figure 3. Gain-Bandwidth Product and Phase Margin Test Circuit**

### typical values

Typical values as presented in this data sheet represent the median (50% point) of device parametric performance.

### input bias and offset current

At the picoampere bias-current level typical of the TLE2161, TLE2161A, and TLE2161B, accurate measurement of the bias current becomes difficult. Not only does this measurement require a picoammeter, but test socket leakages can easily exceed the actual device bias currents. To accurately measure these small currents, Texas Instruments uses a two-step process. The socket leakage is measured using picoammeters with bias voltages applied but with no device in the socket. The device is then inserted into the socket and a second test that measures both the socket leakage and the device input bias current is performed. The two measurements are then subtracted algebraically to determine the bias current of the device.

## TYPICAL CHARACTERISTICS

### table of graphs

| | | | FIGURE |
|---|---|---|---|
| $V_{IO}$ | Input offset voltage | Distribution | 4 |
| $I_{IB}$ | Input bias current | vs Common-mode voltage | 5 |
| | | vs Temperature | 6 |
| $I_{IO}$ | Input offset current | vs Temperature | 6 |
| $V_{ICR}$ | Common-mode input voltage range limits | vs Temperature | 7 |
| $V_{OM}$ | Maximum peak output voltage swing | vs Output current | 8, 9 |
| | | vs Supply voltage | 10, 11, 12 |
| $V_{O(PP)}$ | Maximum peak-to-peak output voltage | vs Frequency | 13, 14, 15 |
| $A_{VD}$ | Differential voltage amplification | vs Frequency | 16 |
| | | vs Temperature | 17 |
| $I_{OS}$ | Short-circuit output current | vs Time | 18 |
| | | vs Temperature | 19 |
| $z_o$ | Output impedance | vs Frequency | 20 |
| CMRR | Common-mode rejection ratio | vs Frequency | 21 |
| $I_{CC}$ | Supply current | vs Supply voltage | 22 |
| | | vs Temperature | 23 |
| | Pulse response | Small-signal | 24, 25 |
| | | Large-signal | 26, 27 |
| | Noise voltage (referred to input) | 0.1 to 10 Hz | 28 |
| $V_n$ | Equivalent input noise voltage | vs Frequency | 29 |
| THD | Total harmonic distortion | vs Frequency | 30, 31 |
| | Gain-bandwidth product | vs Supply voltage | 32 |
| | | vs Temperature | 33 |
| $\phi_m$ | Phase margin | vs Supply voltage | 34 |
| | | vs Temperature | 35 |
| $\phi$ | Phase shift | vs Frequency | 16 |

## TYPICAL CHARACTERISTICS†

TLE2161
DISTRIBUTION OF
INPUT OFFSET VOLTAGE

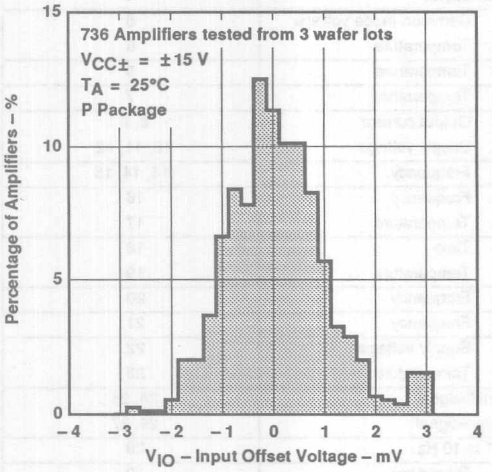


Figure 4

INPUT BIAS CURRENT
vs
COMMON-MODE INPUT VOLTAGE

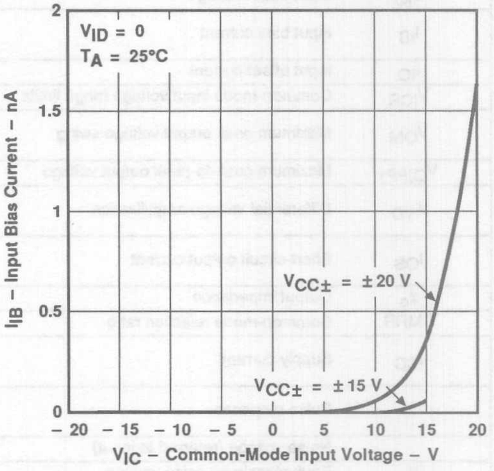


Figure 5

INPUT BIAS CURRENT
and INPUT OFFSET CURRENT
vs
FREE-AIR TEMPERATURE

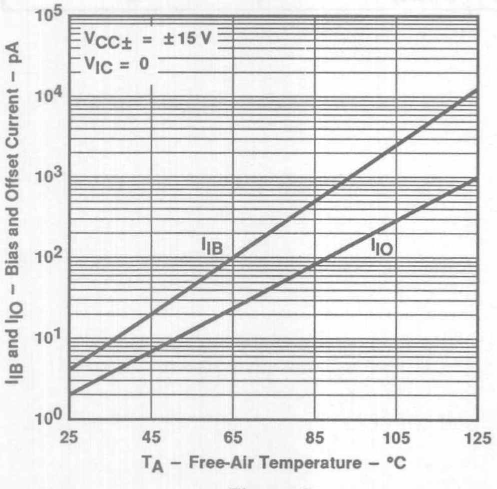


Figure 6

COMMON-MODE
INPUT VOLTAGE RANGE LIMITS
vs
FREE-AIR TEMPERATURE

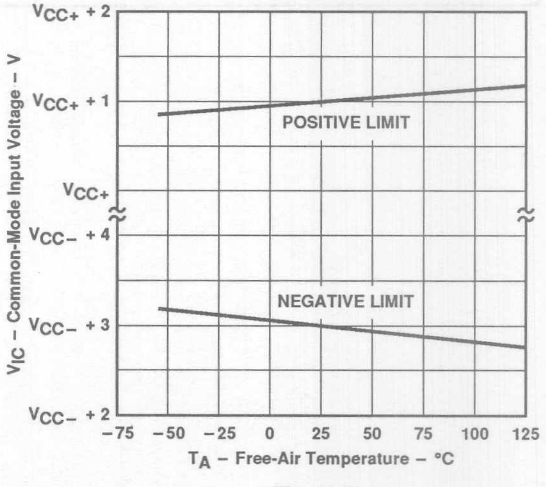


Figure 7

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[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS

MAXIMUM POSITIVE PEAK OUTPUT VOLTAGE
vs
OUTPUT CURRENT

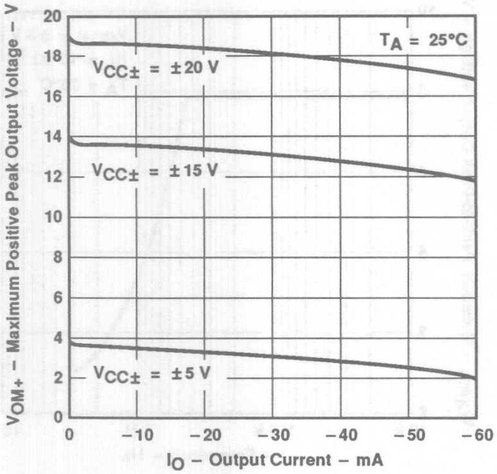

Figure 8

MAXIMUM NEGATIVE PEAK OUTPUT VOLTAGE
vs
OUTPUT CURRENT

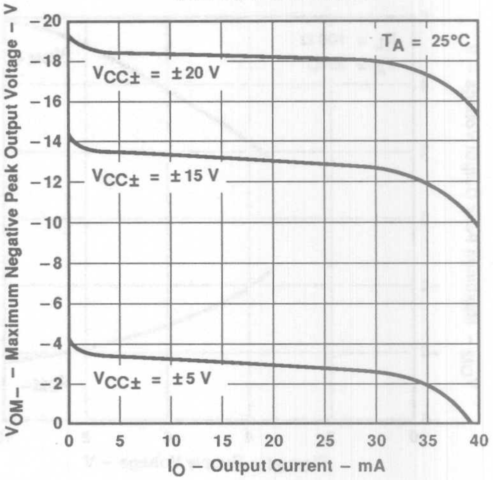

Figure 9

MAXIMUM PEAK OUTPUT VOLTAGE
vs
SUPPLY VOLTAGE

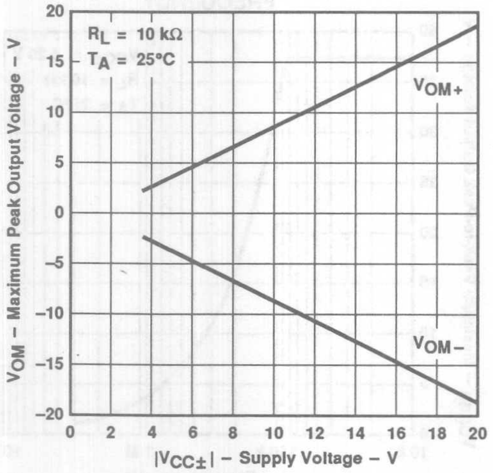

Figure 10

MAXIMUM PEAK OUTPUT VOLTAGE
vs
SUPPLY VOLTAGE

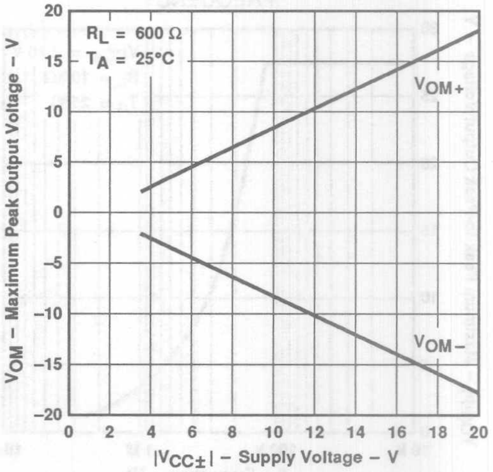

Figure 11

## TYPICAL CHARACTERISTICS

MAXIMUM PEAK OUTPUT VOLTAGE
vs
SUPPLY VOLTAGE

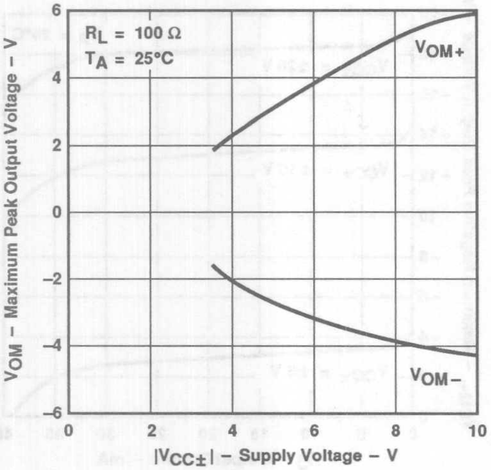

Figure 12

MAXIMUM PEAK-TO-PEAK
OUTPUT VOLTAGE
vs
FREQUENCY

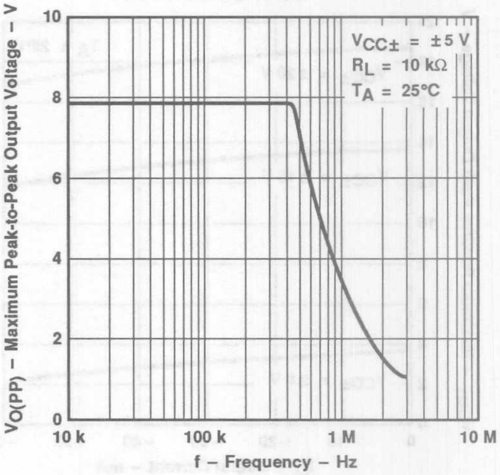

Figure 13

MAXIMUM PEAK-TO-PEAK
OUTPUT VOLTAGE
vs
FREQUENCY

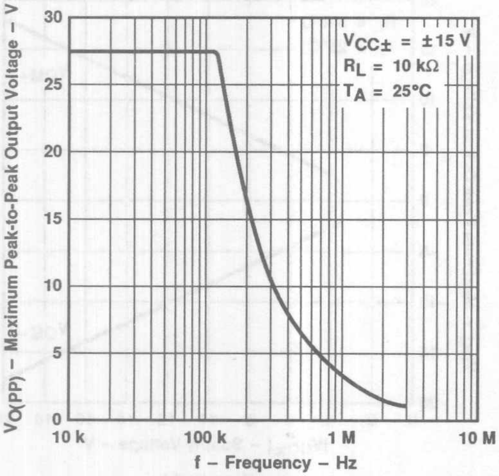

Figure 14

MAXIMUM PEAK-TO-PEAK
OUTPUT VOLTAGE
vs
FREQUENCY

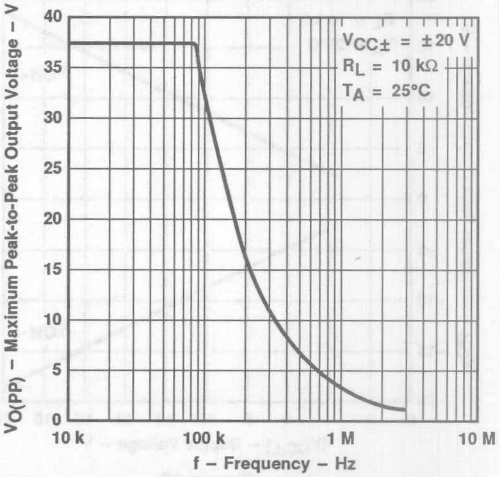

Figure 15

## TYPICAL CHARACTERISTICS[†]

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION and PHASE SHIFT
vs
FREQUENCY

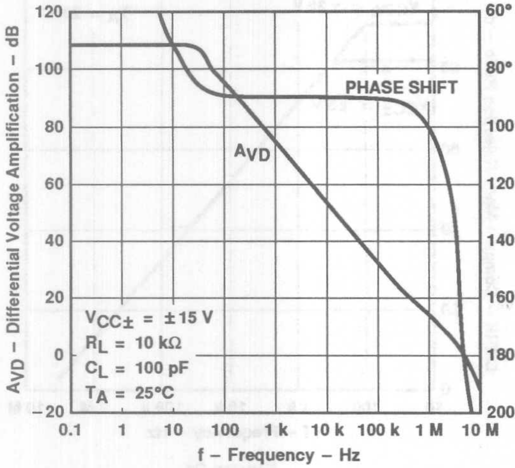

Figure 16

LARGE-SIGNAL VOLTAGE AMPLIFICATION
vs
FREE-AIR TEMPERATURE

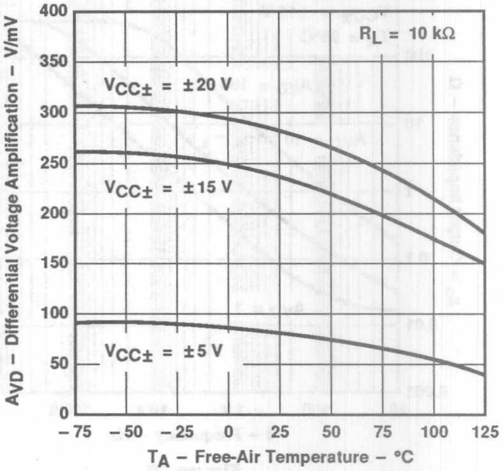

Figure 17

SHORT-CIRCUIT OUTPUT CURRENT
vs
ELAPSED TIME

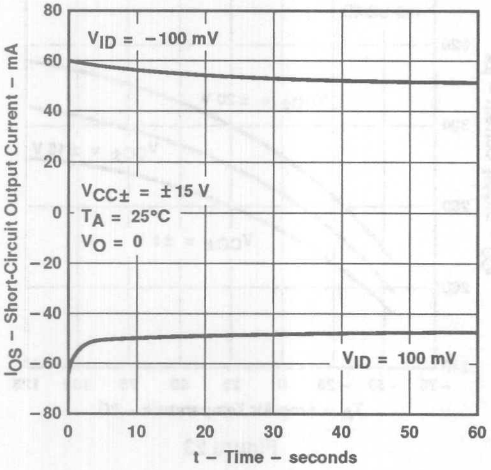

Figure 18

SHORT-CIRCUIT OUTPUT CURRENT
vs
FREE-AIR TEMPERATURE

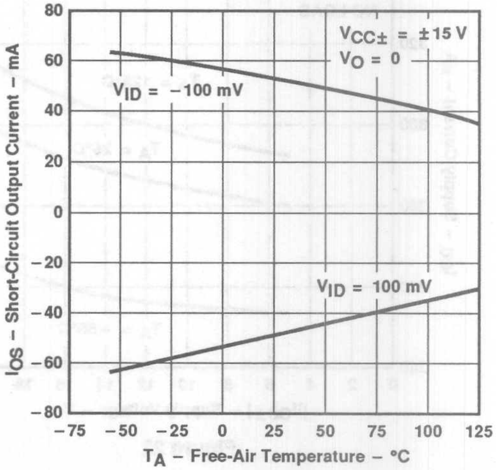

Figure 19

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[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS†

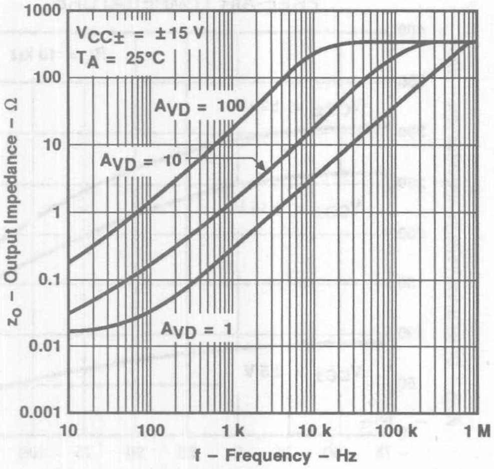
OUTPUT IMPEDANCE
vs
FREQUENCY

Figure 20

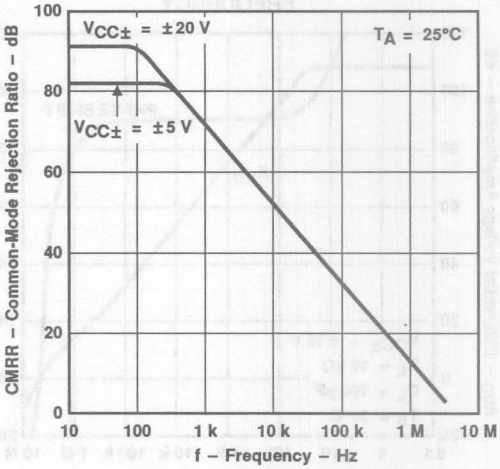
COMMON-MODE REJECTION RATIO
vs
FREQUENCY

Figure 21

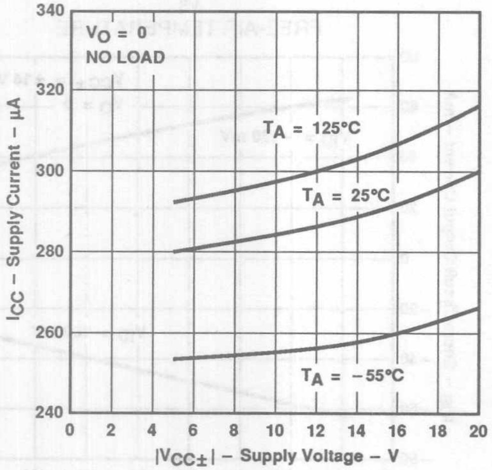
SUPPLY CURRENT
vs
SUPPLY VOLTAGE

Figure 22

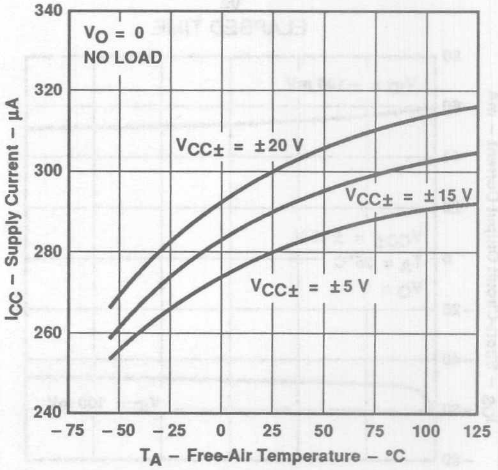
SUPPLY CURRENT
vs
FREE-AIR TEMPERATURE

Figure 23

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†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## TYPICAL CHARACTERISTICS

SMALL-SIGNAL
PULSE RESPONSE

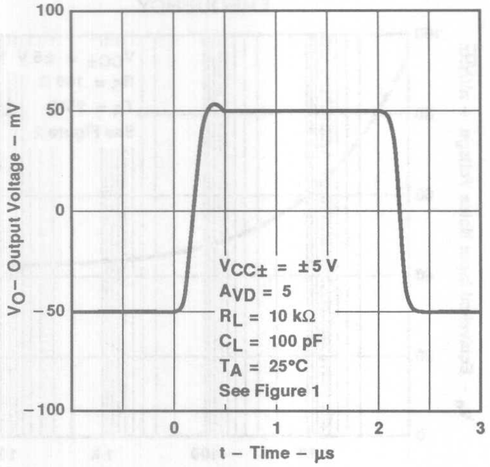


Figure 24

SMALL-SIGNAL
PULSE RESPONSE

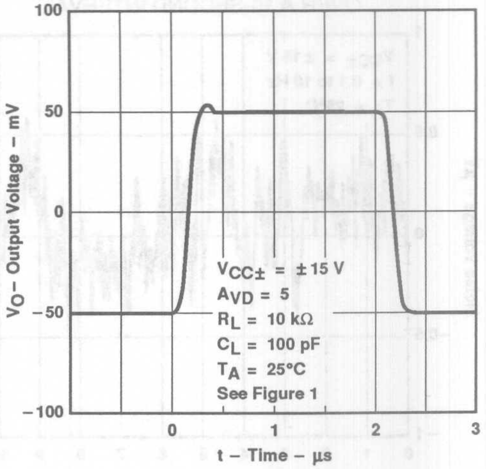


Figure 25

LARGE-SIGNAL
PULSE RESPONSE

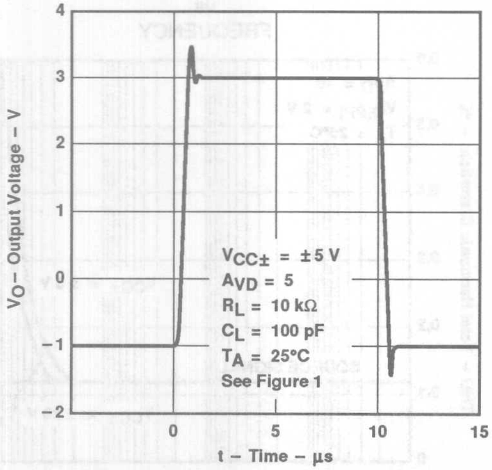


Figure 26

LARGE-SIGNAL
PULSE RESPONSE

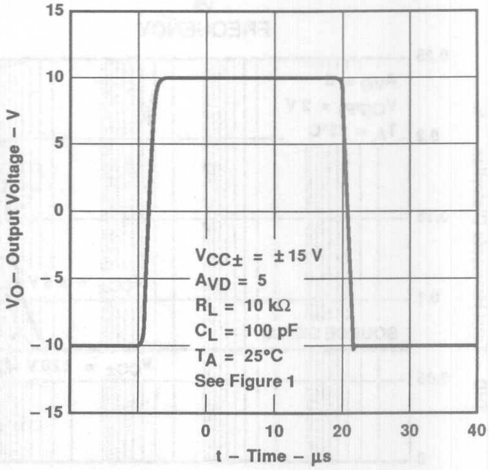


Figure 27

## TYPICAL CHARACTERISTICS

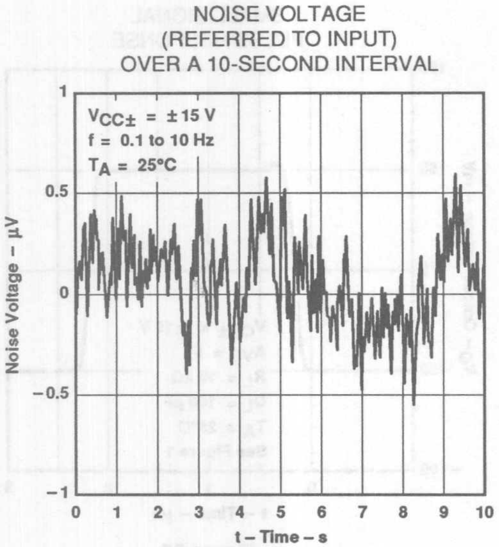


Figure 28

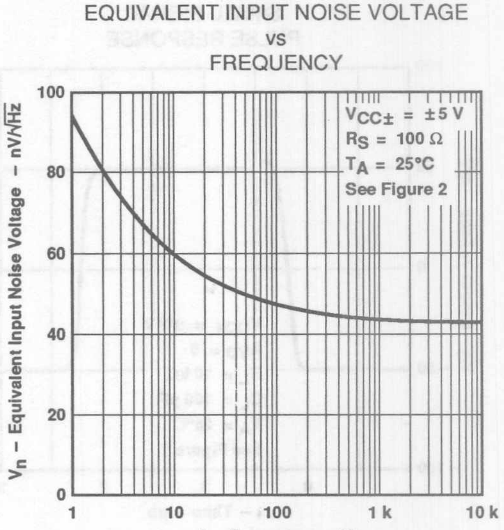


Figure 29

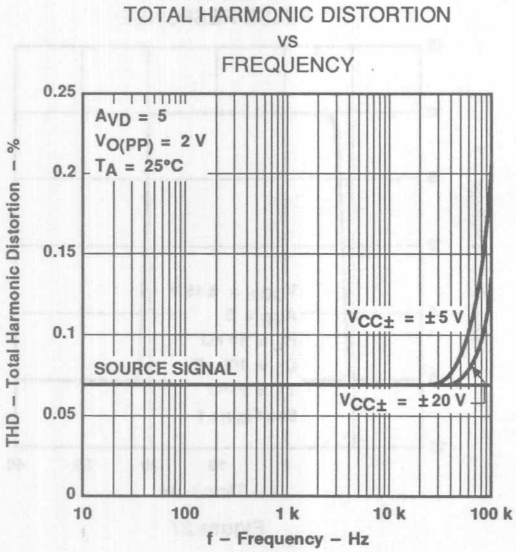


Figure 30

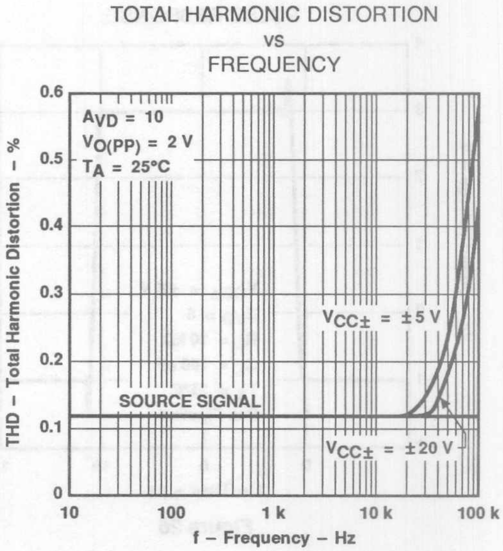


Figure 31

## TYPICAL CHARACTERISTICS[†]

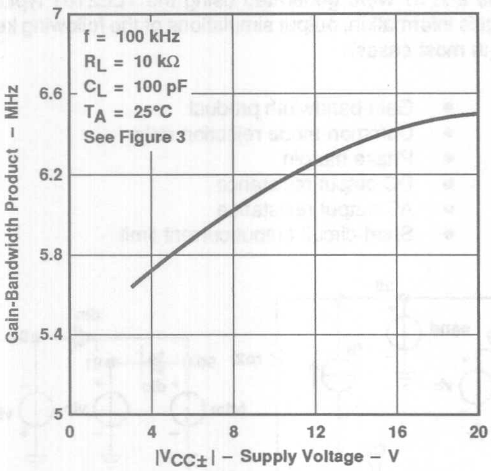

GAIN-BANDWIDTH PRODUCT
vs
SUPPLY VOLTAGE

Figure 32

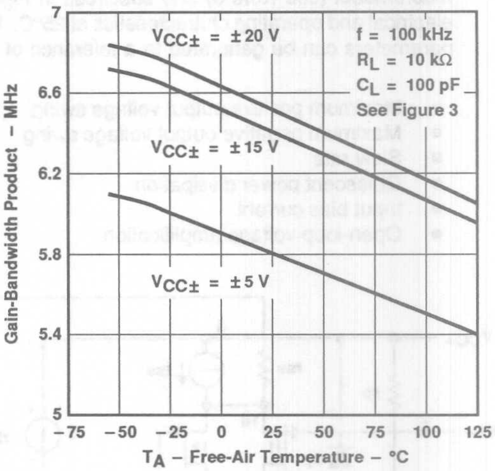

GAIN-BANDWIDTH PRODUCT
vs
FREE-AIR TEMPERATURE

Figure 33

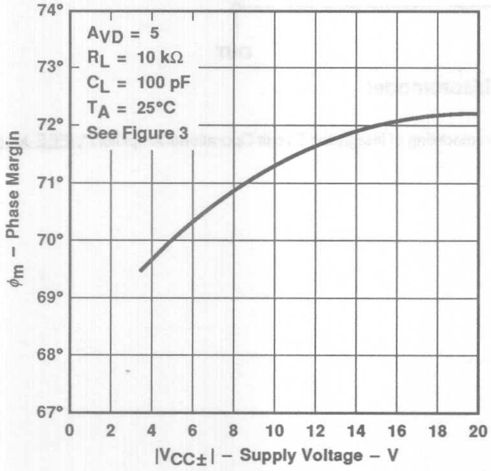

PHASE MARGIN
vs
SUPPLY VOLTAGE

Figure 34

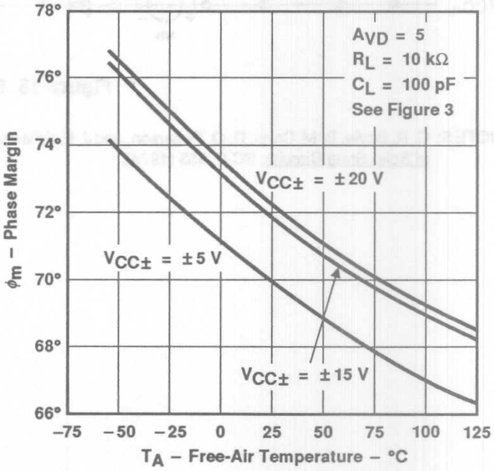

PHASE MARGIN
vs
FREE-AIR TEMPERATURE

Figure 35

---

[†] Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

## APPLICATION INFORMATION

### macromodel information

Macromodel information provided was derived using *PSpice® Parts™* model generation software. The Boyle macromodel (see Note 5) and subcircuit in Figures 36 and 37 were generated using the TLE2161 typical electrical and operating characteristics at 25°C. Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

- Maximum positive output voltage swing
- Maximum negative output voltage swing
- Slew rate
- Quiescent power dissipation
- Input bias current
- Open-loop voltage amplification
- Gain-bandwidth product
- Common-mode rejection ratio
- Phase margin
- DC output resistance
- AC output resistance
- Short-circuit output current limit

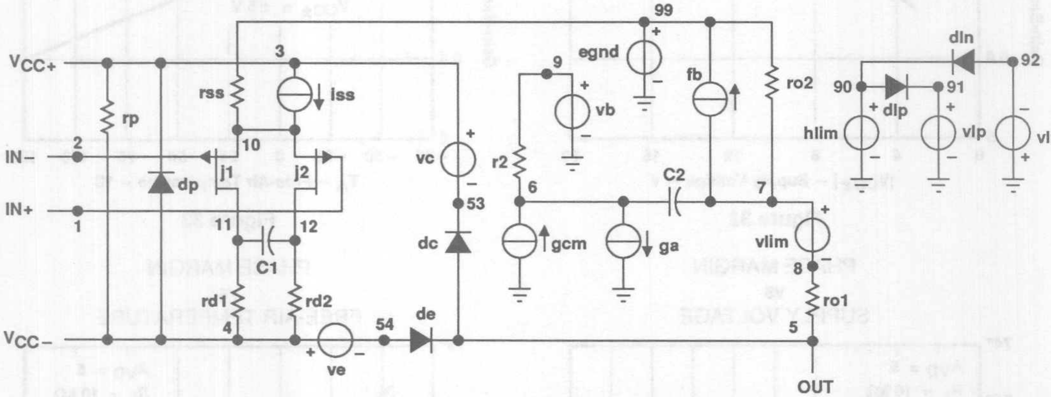


Figure 36. Boyle Macromodel

NOTE 5: G. R. Boyle, B. M. Cohn, D. O. Pederson, and J. E. Solomon, "Macromodeling of Integrated Circuit Operational Amplifiers", IEEE Journal of Solid-State Circuits, SC-9, 353 (1974).

*PSpice* is a registered trademark of MicroSim Corporation.
*Parts* is a trademark of MicroSim Corporation.

**Macromodels, simulation models, or other models provided by TI, directly or indirectly, are not warranted by TI as fully representing all of the specifications and operating characteristics of the semiconductor product to which the model relates.**

## APPLICATION INFORMATION

### macromodel information (continued)

```
.subckt TLE2161  1 2 3 4 5
  c1   11 12 125.4E-14
  c2    6  7 5.000E-12
  dc    5 53 dx
  de   54  5 dx
  dlp  90 91 dx
  dln  92 90 dx
  dp    4  3 dx
  egnd 99  0 poly(2)  (3,0)  (4,0) 0 .5 .5
  fb    7 99 poly(5) vb vc ve vlp vln 0 4.085E6 -4E6 4E6 4E6 -4E6
  ga    6  0 11 12 201.1E-6
  gcm   0  6 10 99 3.576E-9
  iss   3 10 dc 45.00E-6
  hlim 90  0 vlim 1K
  j1   11  2 10 jx
  j2   12  1 10 jx
  r2    6  9 100.0E3
  rd1   4 11 4.973E3
  rd2   4 12 4.973E3
  ro1   8  5 280
  ro2   7 99 280
  rp    3  4 113.2E3
  rss  10 99 4.444E6
  vb    9  0 dc 0
  vc    3 53 dc 2
  ve   54  4 dc 2
  vlim  7  8 dc 0
  vlp  91  0 dc 50
  vln   0 92 dc 50
.model dx D(Is=800.0E-18)
.model jx PJF(Is=1.000E-12 Beta=480E-6 Vto=-1)
.ends
```

Figure 37. Marcomodel Subcircuit

## APPLICATION INFORMATION

### input characteristics

The TLE2161, TLE2161A and TLE2161B are specified with a minimum and a maximum input voltage that, if exceeded at either input, could cause the device to malfunction.

Because of the extremely high input impedance and resulting low bias-current requirements, the TLE2161, TLE2161A, and TLE2161B are well-suited for low-level signal processing; however, leakage currents on printed circuit boards and sockets can easily exceed bias-current requirements and cause degradation in system performance. It is a good practice to include guard rings around inputs (see Figure 38). These guards should be driven from a low-impedance source at the same voltage level as the common-mode input.

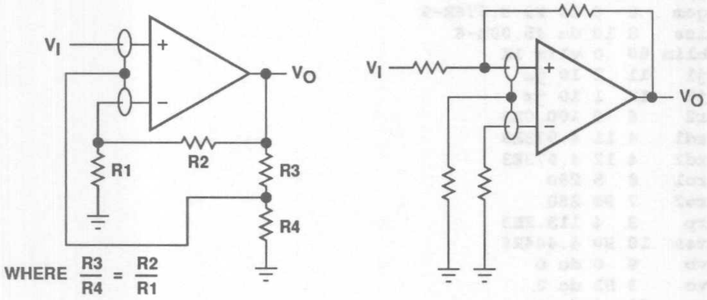


Figure 38. Use of Guard Rings

### input offset voltage nulling

The TLE2161 series offers external null pins that can be used to further reduce the input offset voltage. The circuit of Figure 39 can be connected as shown if the feature is desired. If external nulling is not needed, the null pins may be left disconnected.

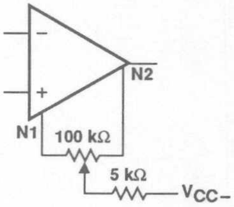


Figure 39. Input Offset Voltage Nulling

# TLE2425C, TLE2425Y
# PRECISION VIRTUAL GROUND

D3824, MARCH 1991

## available features

- **2.5 V Virtual Ground for 5-V/GND Analog Systems**
- **Self-Contained in a 3-terminal TO-226AA Package**
- **High Output Current Capability**
  **Sink . . . 20 mA Typ**
  **Source . . . 20 mA Typ**
- **Micropower Operation . . . 170 µA Typ**
- **Excellent Regulation Characteristics**
  **Output Regulation = 45 µV Typ, $I_O$ = 0 to ±10mA**
  **Input Regulation = 1.5 µV/V Typ**
- **Low-Impedance Output . . . 0.0075 Ω Typ**

## description

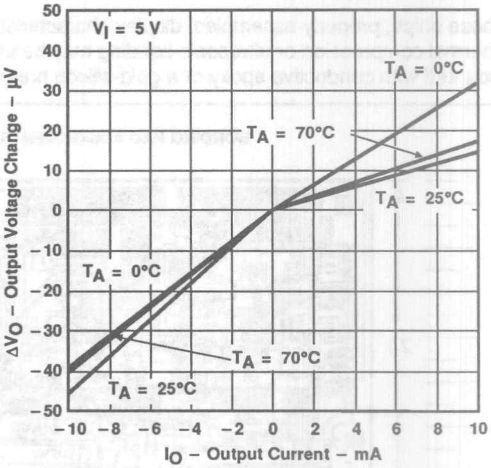
In signal-conditioning applications using a single power source, a reference voltage is required for termination of all signal grounds. To accomplish this, engineers have typically used solutions consisting of resistors, capacitors, operational amplifiers, and voltage references. Texas Instruments has eliminated all of those components with one easy-to-use three-terminal device. That device is the TLE2425 precision virtual ground.

Use of the TLE2425 over other typical circuit solutions gives the designer increased dynamic signal range, improved signal-to-noise ratio, lower distortion, improved signal accuracy, and easier interfacing to ADCs and DACs. These benefits are the result of combining a precision micropower voltage reference and a high-performance precision operational amplifier in a single silicon chip. It is the precision and performance of these two circuit functions together that yield such dramatic system-level performance.

The TLE2425 improves input regulation as well as output regulation, and in addition reduces output impedance and power dissipation in a majority of virtual-ground-generation circuits. Both input regulation and load regulation exceed 12 bits of accuracy on a single 5-V system. Signal-conditioning front-ends of data acquisition systems that push 12 bits and beyond can use the TLE2425 to eliminate a major source of system error.

The TLE2425C is characterized for operation from 0°C to 70°C.

**OUTPUT REGULATION**
**vs**
**OUTPUT CURRENT**



**AVAILABLE OPTIONS**

| $T_A$ | PACKAGE | | |
|---|---|---|---|
| | SMALL-OUTLINE (D) | PLASTIC TO-226AA (LP) | CHIP FORM (Y) |
| 0°C to 70°C | TLE2425CD | TLE2425CLP | TLE2425Y |

D packages are available taped and reeled. Add "R" suffix to device type (e.g., TLE2425CDR).

PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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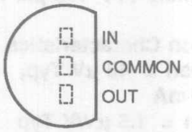
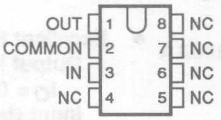
**TLE2425C . . . LP PACKAGE**
**(TOP VIEW)**



**TLE2425C . . . D OR JG PACKAGE**
**(TOP VIEW)**

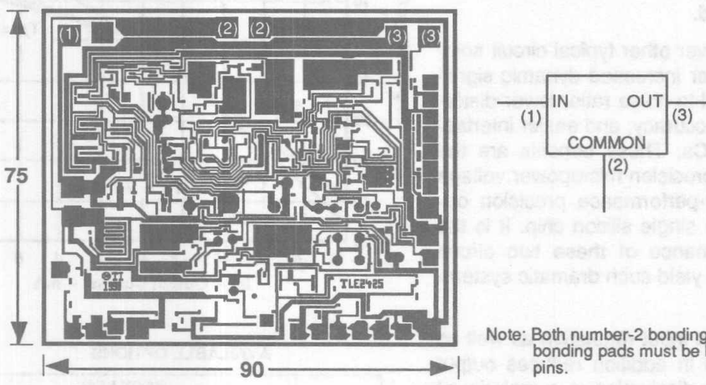


NC – No internal connection.

## TLE2425Y chip information

These chips, properly assembled, display characteristics similiar to the TLE2425, (see electrical table on page 5). Thermal compression or ultrasonic bonding may be used on the doped aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.

**BONDING PAD ASSIGNMENTS**



**CHIP THICKNESS:**
**15 TYPICAL**

**BONDING PADS:**
**4 X 4 MINIMUM**

**$T_{JMAX}$ = 150°C**

**TOLERANCES**
**ARE ± 10%**

**ALL DIMENSIONS**
**ARE IN MILS**

Note: Both number-2 bonding pads and both number-3 bonding pads must be bonded out to the corresponding pins.

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|---|
| Continuous input voltage | 40 V |
| Output current, $I_O$ | ±50 mA |
| Duration of short-circuit current at (or below) 25°C (see Note 1) | unlimited |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range, $T_A$: C-suffix | 0°C to 70°C |
| Storage temperature range | –65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG or LP package | 300°C |

NOTE 1: The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

**DISSIPATION RATING TABLE**

| PACKAGE | $T_A \le 25°C$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25°C$ | $T_A = 70°C$ POWER RATING |
|---|---|---|---|
| D | 725 mW | 5.8 mW/°C | 464 mW |
| JG | 1050 mW | 8.4 mW/°C | 672 mW |
| LP | 775 mW | 6.2 mW/°C | 496 mW |

## recommended operating conditions

| | MIN | MAX | UNIT |
|---|---|---|---|
| Input voltage, $V_I$ | 4 | 40 | V |
| Operating free-air temperature, $T_A$: C-suffix | 0 | 70 | °C |

## electrical characteristics at specified free-air temperature, $V_I$ = 5 V, $I_O$ = 0 (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$[†] | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_O$ | Output voltage | | | 25°C | 2.48 | 2.50 | 2.52 | V |
| | | | | Full range | 2.47 | | 2.53 | |
| $\alpha_{VO}$ | Temperature coefficient of output voltage | | | 25°C | | 20 | | ppm/°C |
| | Bias current | $I_O$ = 0 | | 25°C | | 170 | 250 | μA |
| | | | | Full range | | | 250 | |
| | Input regulation | $V_I$ = 4.5 V to 5.5 V | | 25°C | | 1.5 | 20 | μV |
| | | | | Full range | | | 25 | |
| | | $V_I$ = 4 V to 40 V | | 25°C | | 1.5 | 20 | μV/V |
| | | | | Full range | | | 25 | |
| | Ripple rejection | f = 120 Hz, $\Delta V_{I(PP)}$ = 1 V | | 25°C | | 80 | | dB |
| | Output regulation[‡] (source current) | $I_O$ = 0 to −10 mA | | 25°C | | 45 | 160 | μV |
| | | | | Full range | | | 250 | |
| | | $I_O$ = 0 to −20 mA, | | 25°C | | 150 | 450 | |
| | Output regulation[‡] (sink current) | $I_O$ = 0 to 10 mA | | 25°C | | 15 | 160 | μV |
| | | | | Full range | | | 250 | |
| | | $I_O$ = 0 to 20 mA, | | 25°C | | 65 | 235 | |
| | Long-term stability of output voltage | Δt = 1000 h, Noncumulative | | 25°C | | 15 | | ppm |
| $z_O$ | Output impedance | | | 25°C | | 7.5 | 22.5 | mΩ |
| | Short-circuit output current | Sink current, $V_O$ = 5 V | | 25°C | 30 | 55 | | mA |
| | | Source current, $V_O$ = 0 | | | −30 | −50 | | |
| | Output noise voltage, rms | f = 10 Hz to 10 kHz | | 25°C | | 100 | | μV |
| | Output voltage response to output current step | $V_O$ to 0.1%, $I_O$ = ± 10 mA | $C_L$ = 0 | 25°C | | 110 | | μs |
| | | | $C_L$ = 100 pF | | | 115 | | |
| | | $V_O$ to 0.01%, $I_O$ = ± 10 mA | $C_L$ = 0 | | | 180 | | |
| | | | $C_L$ = 100 pF | | | 180 | | |
| | Output voltage response to input voltage step | $V_I$ = 4.5 to 5.5 V, $V_O$ to 0.1% | | 25°C | | 12 | | μs |
| | | $V_I$ = 4.5 to 5.5 V, $V_O$ to 0.01% | | | | 30 | | |
| | Output voltage turn-on response | $V_I$ = 0 to 5 V, $V_O$ to 0.1% | | 25°C | | 125 | | μs |
| | | $V_I$ = 0 to 5 V, $V_O$ to 0.01% | | | | 210 | | |

[†] Full range is 0°C to 70°C.
[‡] Sample tested.

## electrical characteristics at $V_I$ = 5 V, $I_O$ = 0, $T_A$ = 25°C (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $V_O$ | Output voltage | | | 2.48 | 2.50 | 2.52 | V |
| $\alpha_{VO}$ | Temperature coefficient of output voltage | | | | 20 | | ppm/°C |
| | Bias current | $I_O = 0$ | | | 170 | 250 | μA |
| | Input regulation | $V_I$ = 4.5 V to 5.5 V | | | 1.5 | 20 | μV |
| | | $V_I$ = 4 V to 40 V | | | 1.5 | 20 | μV/V |
| | Ripple rejection | f = 120 Hz, $\Delta V_{I(PP)}$ = 1 V | | | 80 | | dB |
| | Output regulation‡ (source current) | $I_O$ = 0 to –10 mA | | | 45 | 160 | μV |
| | | $I_O$ = 0 to –20 mA, | | | 150 | 450 | |
| | Output regulation‡ (sink current) | $I_O$ = 0 to 10 mA | | | 15 | 160 | μV |
| | | $I_O$ = 0 to 20 mA, | | | 65 | 235 | |
| $z_o$ | Output impedance | | | | 7.5 | 22.5 | mΩ |
| | Short-circuit output current | Sink current, $V_O$ = 5 V | | 30 | 55 | | mA |
| | | Source current, $V_O$ = 0 | | –30 | –50 | | |
| | Output noise voltage, rms | f =10 Hz to 10 kHz | | | 100 | | μV |
| | Output voltage response to output current step | $V_O$ to 0.1%, $I_O$ = ± 10 mA | $C_L$ = 0 | | 110 | | μs |
| | | | $C_L$ = 100 pF | | 115 | | |
| | | $V_O$ to 0.01%, $I_O$ = ± 10 mA | $C_L$ = 0 | | 180 | | |
| | | | $C_L$ = 100 pF | | 180 | | |
| | Output voltage response to input voltage step | $V_I$ = 4.5 to 5.5 V, $V_O$ to 0.1% | | | 12 | | μs |
| | | $V_I$ = 4.5 to 5.5 V, $V_O$ to 0.01% | | | 30 | | |
| | Output voltage turn-on response | $V_I$ = 0 to 5 V, $V_O$ to 0.1% | | | 125 | | μs |
| | | $V_I$ = 0 to 5 V, $V_O$ to 0.01% | | | 210 | | |

‡Sample tested.

## TYPICAL CHARACTERISTICS

| | TABLE OF GRAPHS | | FIGURE |
|---|---|---|---|
| $V_O$ | Output voltage | Distribution | 1 |
| | | vs Temperature | 2 |
| | Output voltage hysteresis | vs Temperature | 3 |
| | Bias current | vs Input voltage | 4 |
| | | vs Temperature | 5 |
| | Input regulation | vs Input voltage | 6 |
| | Ripple rejection | vs Frequency | 7 |
| | Output regulation | vs Output current | 8 |
| $z_o$ | Output impedance | vs Frequency | 9 |
| $I_{OS}$ | Short-circuit output current | vs Temperature | 10 |
| $V_n$ | Spot noise voltage | vs Frequency | 11 |
| | Wideband noise voltage | vs Frequency | 12 |
| | Output voltage change with current step | vs Time | 13 |
| | Output voltage change with voltage step | vs Time | 14 |
| | Output voltage power-up response | vs Time | 15 |
| | Stability Range | vs Load Capacitance | 16 |

## TYPICAL CHARACTERISTICS

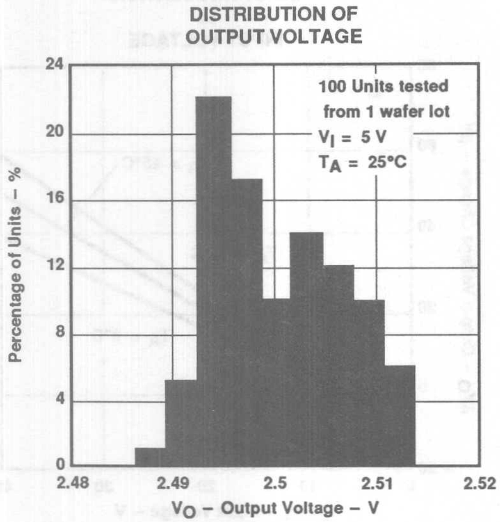


Figure 1

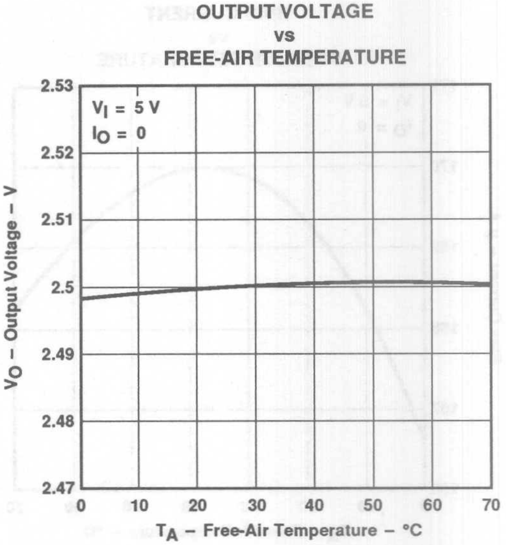


Figure 2

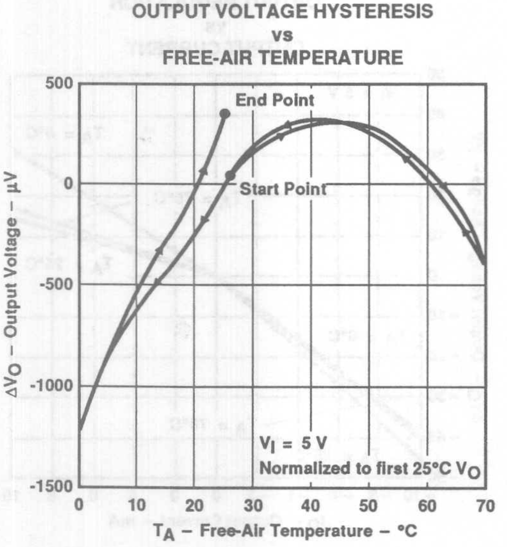


Figure 3

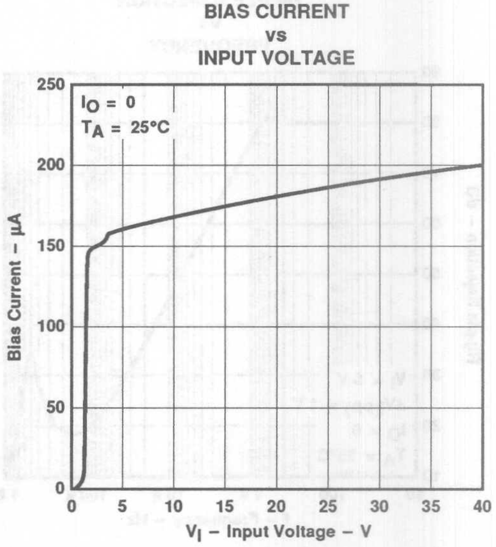
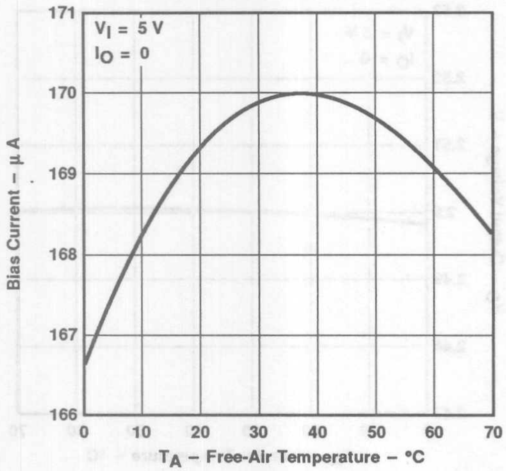


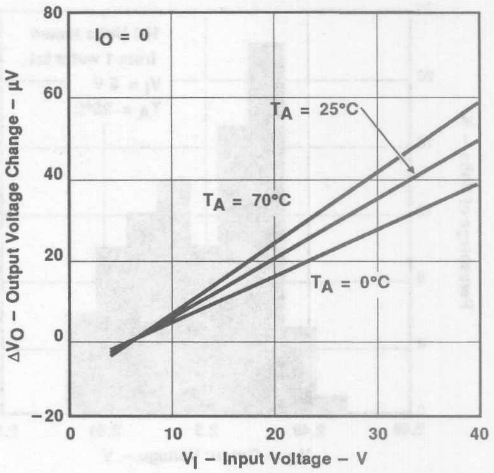
Figure 4

## TYPICAL CHARACTERISTICS



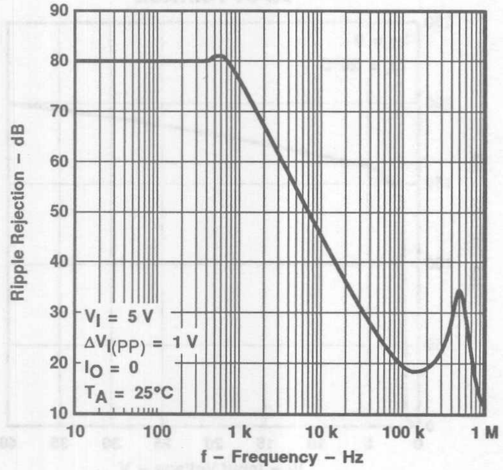
**BIAS CURRENT vs FREE-AIR TEMPERATURE**

Figure 5



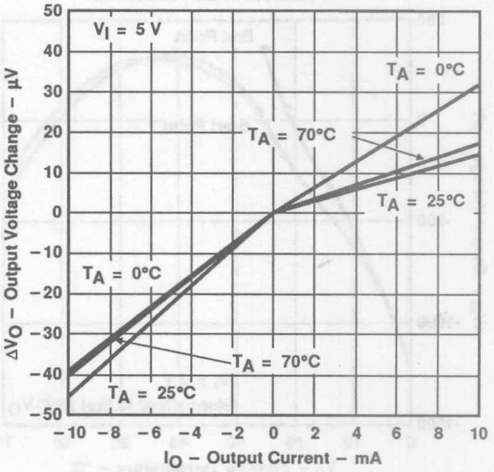
**INPUT REGULATION vs INPUT VOLTAGE**

Figure 6



**RIPPLE REJECTION vs FREQUENCY**

Figure 7



**OUTPUT REGULATION vs OUTPUT CURRENT**

Figure 8

## TYPICAL CHARACTERISTICS

OUTPUT IMPEDANCE
vs
FREQUENCY

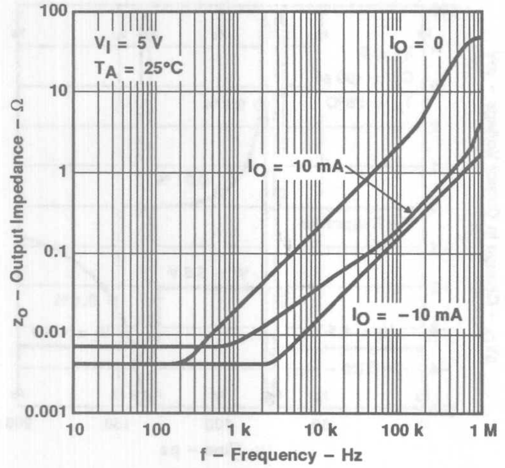


Figure 9

SHORT-CIRCUIT OUTPUT CURRENT
vs
FREE-AIR TEMPERATURE

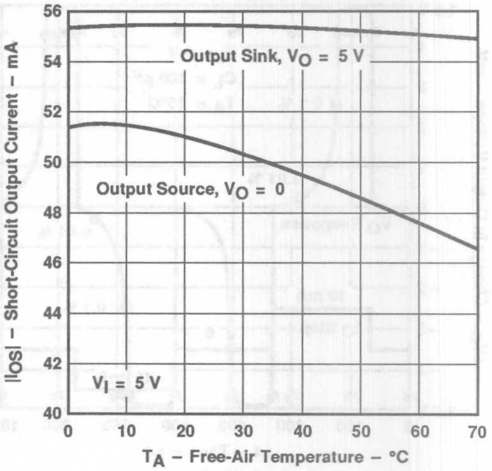


Figure 10

SPOT NOISE VOLTAGE
vs
FREQUENCY

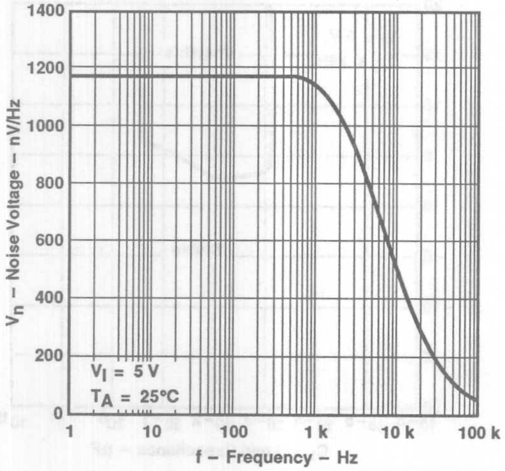


Figure 11

WIDEBAND NOISE VOLTAGE
vs
FREQUENCY

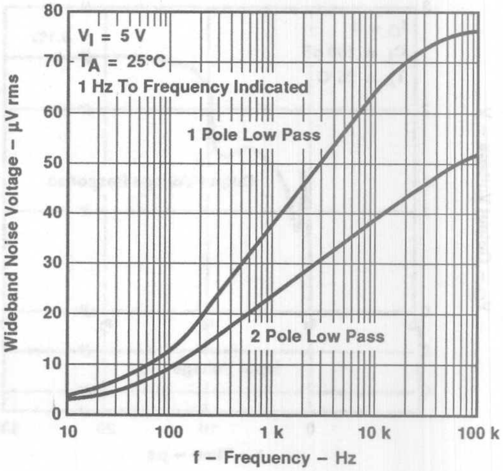


Figure 12

## TYPICAL CHARACTERISTICS

### OUTPUT VOLTAGE RESPONSE TO OUTPUT CURRENT STEP vs TIME

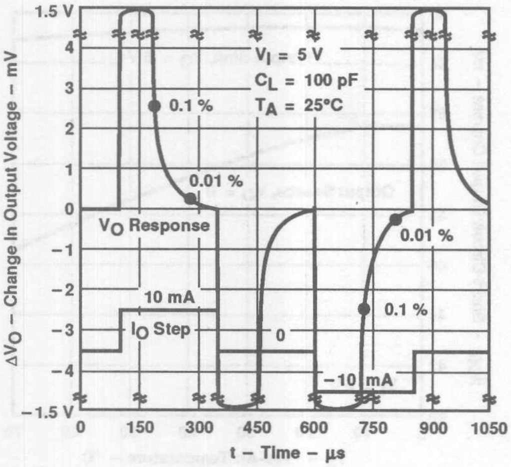


Figure 13

### OUTPUT VOLTAGE RESPONSE TO INPUT VOLTAGE STEP vs TIME

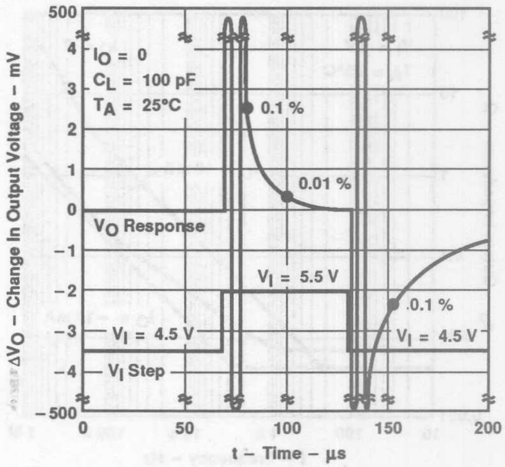


Figure 14

### OUTPUT VOLTAGE POWER-UP RESPONSE vs TIME

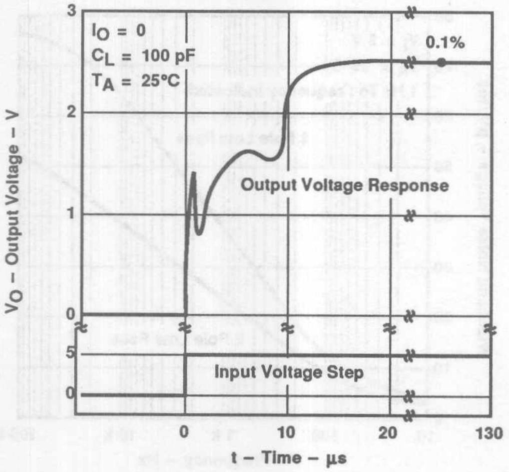


Figure 15

### STABILITY RANGE vs LOAD CAPACITANCE

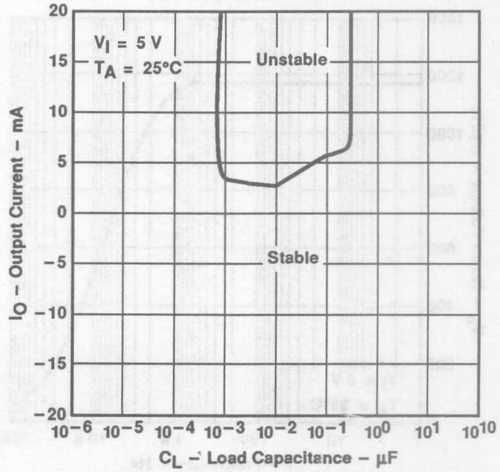


Figure 16